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Received: 17 January 2023 | Revised: 13 June 2023 | Accepted: 22 June 2023

DOI: 10.1002/erv.3008

WILEY

RESEARCH ARTICLE

Linguistic embodiment in typical and atypical anorexia nervosa: Evidence from an image-word matching task

Paolo Meneguzzo[1,2] | **David Dal Brun**[3] | **Enrico Collantoni**[1,2] | **Valentina Meregalli**[1,2] | **Patrizia Todisco**[4] | **Angela Favaro**[1,2] | **Elena Tenconi**[1,2]

[1]Department of Neuroscience, University of Padova, Padova, Italy

[2]Padova Neuroscience Center, University of Padova, Padova, Italy

[3]Department of Linguistic and Literary Studies, University of Padova, Padova, Italy

[4]Eating Disorders Unit, Casa di Cura "Villa Margherita, Vicenza, Italy

Correspondence
Paolo Meneguzzo, Department of Neuroscience, University of Padova, via Giustiniani 2, 35128, Padova, Italy.
Email: paolo.meneguzzo@unipd.it

Handling Editor: Daniel Le Grange

Funding information
Italian Ministry of Education (MIUR)

Abstract

Objective: The integration of sensory, motor, and cognitive systems is embodied cognition, according to which mind and body are not separate and distinct, and our body (and our brain, as part of the body) contributes to determining our mental and cognitive processes. In spite of limited data available, Anorexia nervosa (AN) appears as a condition in which embodied cognition is altered, in particular, if we consider bodily sensations and visuospatial information processing. We aimed to evaluate the ability to correctly identify body parts and actions in both full (AN) and atypical AN (AAN), looking at the role of the underweight status.

Method: A group of 143 females (AN = 45, AAN = 43, unaffected women = 55) was enrolled. All participants performed a linguistic embodied task to evaluate the association between a picture—showing a bodily action—and a written verb. Additionally, a subsample of 24 AN participants performed a retest after stable weight recovery.

Results: Both AN and AAN demonstrated an abnormal ability to evaluate the picture-written verb associations, especially if the involved bodily effectors were the same in both stimuli (i.e., pictorial and verbal) and needed a longer response time.

Conclusions: Specific embodied cognition linked to body schema seems to be impaired in persons with AN. The longitudinal analysis showed a difference between AN and AAN only in the underweight condition, suggesting the presence of an abnormal linguistic embodiment. More attention should be devoted to embodiment during AN treatment to improve bodily cognition, which might, in turn, diminish body misperception.

KEYWORDS
anorexia nervosa, atypical anorexia nervosa, body schema, embodied cognition, embodiment

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Highlights

- Linguistic approach provides new insights into the theory of embodiment
- Linguistic embodiment appears altered in patients with anorexia nervosa
- No significant differences between typical and atypical anorexia nervosa emerged
- After weight recovery, patients with anorexia nervosa showed improved task ability
- All patients required more time for the embodiment task than controls
- Disembodiment does not appear to be linked to the severity of underweight

1 | INTRODUCTION

Embodiment is defined as "the sense of being identified within one's physical body" and is composed of the sense of ownership, agency, and location (Cebolla et al., 2016; Mehling et al., 2009). Embodiment cognition represents the feeling of being distinct from others and operates by integrating the representation of the body into high-level cognitive processing (Carruthers, 2008; Winkielman et al., 2015). These integrative cognitive processes typically include two different body representations: body image and body schema (Longo et al., 2009). Body image is the perception of one's body—name, size, shape, and judgements—and contributes to defining identity/self and is made up of a series of cognitive, perceptual, affective and behavioural components (De Vignemont, 2010; Tsakiris et al., 2011; van Elk & Blanke, 2011). In contrast, body schema is predominantly somatosensory and is defined as "the awareness of a specific body part's movement" (Gadsby, 2017; Morasso & Mohan, 2021). The body schema concept integrates embodiment information from various brain regions, such as the extrastriate cortex, fusiform gyrus, and right inferior parietal lobe (Beckmann et al., 2021). The integration of body image and body schema represents the central role of embodiment in cognitive processes, combining exteroceptive and interoceptive stimuli, and mediating top-down and bottom-up processes (Badoud & Tsakiris, 2017; Carruthers, 2009; Gallagher, 2001; Iscen et al., 2014).

Linguistic representation of actions is one of the procedures that could mediate embodiment's cognitive processes. Various pieces of evidence support the idea that linguistic meaning is derived from the interaction of experience, sensory perception, motor function, and internal state, which is one of the possible definitions of embodiment (Bach, 2012). Previous studies have shown that linguistic description underlies sensory experience, where functional brain activation matches real events' activation (Bach, 2012; Rueschemeyer et al., 2010). This phenomenon demonstrates the embodied nature of language representations and their connections with the perceptual and motor systems (de Vega et al., 2014; van Dam et al., 2010). Moreover, neuroimaging studies have shown that some of the neural circuitry involved in the execution of motor actions is also activated when the same motor actions are seen, or when language about those motor actions is understood (Fogassi & Ferrari, 2007; Gallese & Cuccio, 2018). This phenomenon has been linked to the mirror system, which has been proposed as a key element for understanding verbal semantics (Van Overwalle & Baetens, 2009). There is scientific evidence suggesting that linguistic semantics is embodied: experiments that have applied lexical matching tasks comparing our task to variants have shown that the results are not linked to memories or to a completely abstract process (Bergen et al., 2003; Cowley, 2014; Evans, 2012). Therefore, this approach might be useful in evaluating the ability of individuals to integrate embodied cognition parts, as it could reveal specific impairments that contribute to a distorted mental representation of the body.

Indeed, integrating different perspectives and approaches has been suggested as the key to improving knowledge about embodiment (Glenberg, 2010). Previous literature has shown that mismatches between action representations and verbs lead to an increase in mistakes in the general population (Bergen et al., 2003), especially in the case of incongruence between the image and the action described by the verb with the involvement of the same effector (i.e., body district). However, no evaluation has ever been conducted on the clinical population.

People with anorexia nervosa (AN) represent a clinical population who may have embodiment difficulties. Indeed, AN is a severe psychiatric condition characterised by a distorted view and judgement of one's own body weight and shape, leading to dysfunctional eating behaviors, weight loss, and severe, life-threatening underweight states (American Psychiatric Association, 2013). The current literature suggests that AN and

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AAN are characterised by the same psychological symptoms and physiological characteristics, as both reported significant weight loss. However, only AN is defined as underweight, while AAN is characterised by normal weight with a significant weight suppression (Walsh et al., 2022).

A patients's body evaluation plays a crucial role in their AN psychopathology, where severe body image disturbances can derange experiences and beliefs (McAdams & Krawczyk, 2014; Morasso & Mohan, 2021). This aspect is considered so impactful that researchers have proposed classifying AN as a body image disorder rather than an eating disorder (Phillipou et al., 2017) despite insufficient evidence and the unclear role of the underweight condition in bodily evaluation in AN and atypical AN (AAN) (Behrens et al., 2020; Glashouwer et al., 2019; Poletti et al., 2022).

One cognitive mechanism that has been proposed for the impaired body image in AN is the presence of an abnormal updating process of body schema, where top-down control plays a key role in updating body schema representations (Riva et al., 2014). Explicit motor imagery abilities are impaired in individuals with AN, indicating difficulties in body schema tasks and motor imagery (Meregalli et al., 2022). Morphological analyses have found a disruption in the integration of somatosensory and visuospatial information in individuals with AN even after weight recovery, indicating that a neural substrate may play a role in the development and maintenance of embodiment impairments and body processing (Favaro et al., 2012). Previous studies have also pointed out that people with AN have impaired exbodiment processes (i.e., bottom-up processes), such as the ability to evaluate affective touch, haptic perception, interoception, nociception, tactile perception, and the internal clock system (Meneguzzo et al., 2022; Teaford et al., 2021; Zatti & Zarbo, 2015). Finally, body image disturbance in AN seems to be modified by sensory perception changes linked to positive embodiment or disembodiment, showing an aspect still poorly evaluated (Burychka et al., 2021; Keizer et al., 2016). Body concerns are more strongly related to embodiment difficulties than body shape perceptions, showing the role of negative bodily feelings and emotions in disembodiment (Provenzano et al., 2020).

Psychodynamic and phenomenological theories have described AN as an embodiment disorder, linked to the alienation of the body and emotions (Cascino et al., 2019; Fuchs, 2021). Moreover, the body has been described as the results of dynamic interaction with the world through metaphors, with the 'concretised metaphor' and the 'psychic equivalence' concepts representing the psychopathological core of AN and the bodily manifestation of the disorder (Skårderud, 2007). Applying a different approach—cognitive science—embodiment has been evaluated as the interaction between the physical body, the local environment, the neural system's complex interplay, and the outside world (Clark, 1999). According to this perspective, embodiment could overcome the dualism between thoughts and bodily experiences of individuals with AN (Morasso & Mohan, 2021), possibly paving a pathway for improved treatments (Kolnes, 2012; Moccia et al., 2022; Musolino et al., 2020; Zatti & Zarbo, 2015), and shedding light on the multidimensional concept of body image (Garcia et al., 2019; Lovell & Banfield, 2022). However, existing data are insufficient and disconnected from cognitive-behavioral treatment options.

Therefore, the present study examined individuals with AN and AAN. We aimed to determine—for the first time—their ability to evaluate the association between bodily actions and motions, integrating visual and linguistic inputs and their connections with body image concerns (defined as embodiment). As pointed out previously, embodied theories of language processing state that internal simulations of actual interactions are reflected in lexical–semantic representations. Thus, in the current study, we investigated whether different reliance on body schema in planning real-world interactions are also reflected in lexical–semantic representations. For this aim, a form of covert cognitive embodiment was considered, using an association of images of bodily figures and text verbs. This approach also used standardized body image questionnaires. A comparison of individuals diagnosed with AAN was included to evaluate the role of body concerns and body weight. Our main hypothesis was that a specific covert task might help to reveal embodiment difficulties in individuals with AN and AAN, indicating the presence of specific cognitive processes. We hypothesised the presence of a prolonged response time in AN and AAN, with more errors if compared to the general population due to the impaired embodiment. We also hypothesised that body weight might have a limited role in these differences due to the shared cognitive focus on body schema and body image, and for this aim we also included a longitudinal analysis after weight restoration in AN, expecting a limited improvement. Our second aim was to evaluate the relationships between body image constructs and embodiment results. We hypothesised that AN and AAN presented different relationships between body image constructs and embodiment task scores compared to the general population, showing possible specific psychological targets for future studies.

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2 | MATERIAL AND METHODS

2.1 | Participants

Our sample consisted of 45 females with AN and 43 females with AAN recruited at the Eating Disorders Center of the University Hospital of Padova (Italy) and the Eating Disorders Unit of the Casa di Cura Villa Margherita (Arcugnano, Italy). These patients were compared to 55 age-matched community women (CW) recruited via public announcements for general psychological evaluations. Diagnoses were made according to the last version of the Diagnostic and Statistical Manual of Mental Disorders (DSM, American Psychiatric Association, 2013). As suggested by previous literature, weight loss of at least 5% of body weight was required, for the diagnosis of AAN (Forney et al., 2017). The inclusion criteria were as follows: females between 16 and 35 years of age. The exclusion criteria for all the participants were as follows: (a) having a severe medical comorbidity (e.g., epilepsy), (b) having a drug dependence, (c) having a history of neurological trauma, or (d) having a specific neuropsychological difficulty (e.g., dyslexia) or a certified intellectual disability. Exclusion criteria for the CW participants also included a history of eating disorders (EDs) or any other psychiatric condition. A trained psychiatrist evaluated the inclusion and exclusion criteria and interviewed all participants using the Structured Clinical Interview for DSM-5 (SCID-5) (Shankman et al., 2018). A subsample of 24 AN-diagnosed participants (53.3%) reached a stable BMI above 18.5 kg/m^2 at the end of the inpatient multidisciplinary cognitive-behavioral treatment. Before being discharged, these participants agreed to participate in a longitudinal evaluation. The treatment comprised once-a week psychotherapy session, daily group psychotherapy, nutritional counselling, nursing care, meal planning, family treatment, psycho-educational group therapy and psychopharmacologic treatment as needed (Todisco, Meneguzzo, Garolla, et al., 2020).

The present study was carried out in accordance with the latest version of the Declaration of Helsinki. The local Research Ethics Committee approved this study and signed informed consent was obtained from all participants (or from the participants' parents for participants under 18 years old).

2.2 | Measures and procedure

2.2.1 | Self-report questionnaire

As part of the research protocol, each participant completed self-report questionnaires before the experimental session. This information was used to evaluate specific eating psychopathology and body image concerns. Body image concerns were evaluated with Subscale A of the Body Uneasiness Test (BUT), a 34-item self-report questionnaire that investigates negative experiences, thoughts, and emotions connected to the body (Cuzzolaro et al., 2006). It comprises five subscales: weight phobia (WP, in the current study Cronbach's $\alpha = 0.871$), body image concern (BIC, $\alpha = 0.906$), avoidance (A, $\alpha = 0.814$), compulsive self-monitoring (CSM, $\alpha = 0.838$), and depersonalisation (D, $\alpha = 0.815$).

2.2.2 | Computerised task

The computerised task for the evaluation of the embodiment was implemented with OpenSesame (https://osdoc.cogsci.nl/). The task was based on an image-verb matching task proposed by the literature to evaluate the cognitive processes linked to embodied verbal semantics (Bergen et al., 2003).

In cognitive neuroscience, embodiment is defined as the integration of data from perception and motor control (Raja, 2022). The task we used is based on this assumption and evidence about the embodied nature of language. Previous experiments have shown that when someone understands language, effector-specific neurocognitive representations during picture perception and action word understanding are activated (Bergen et al., 2010).

Forty-eight stick-figure images representing three body effectors—mouth, hands, and legs—were prepared for the task. See Figure 1 for an illustration. For the linguistic adaptation, two authors (DDB and PM) independently translated the verbs into Italian, and a third author (ET) sorted out any disagreements between the first two authors. A fourth author (EC) also independently translated the Italian verbs back to English, checking the adaptation.

The task started with a fixation cross in the center of the screen. Next, one of the figures was shown in the center of the screen for 1000 ms. Afterwards, a visual mask was presented for 450 ms to reduce the priming effects resulting from the visual imagery, and then a black screen was shown for 50 ms. Finally, a verb appeared in the screen's center until the participant pressed the button to indicate whether the verb was (I) or was not (O) a good description of the action depicted in the figure. The verb could be any of the following: a matching verb, a non-matching verb with the same body effector (NM-SE), or a non-matching verb with a different body effector (NM-DE). According to the previous literature that analysed the general population, an NM-SE response should have a slower reaction time than a

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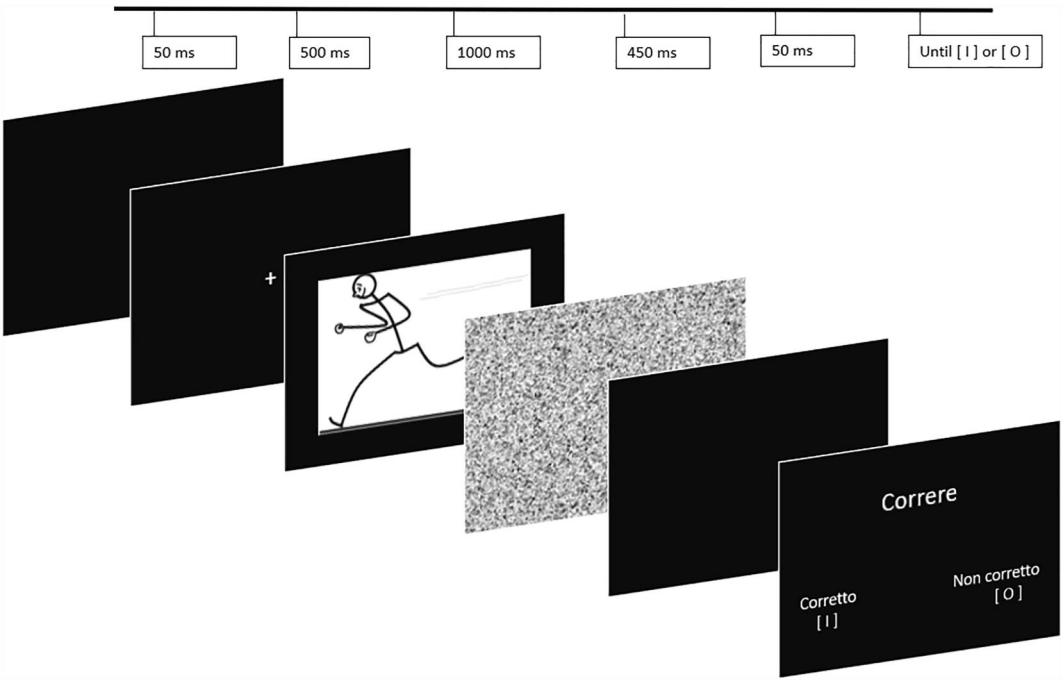

FIGURE 1 Graphical representation of the task applied, with the presentation times of each screen. In this example, the figure was matched with the verb "Run" (in the figure is represented the Italian word "Correre"), showing a matched pair.

matching or NM-DE response due to cognitive interference linked to the same mirror circuitry recruited for evaluating the responses, a sort of "embodied cost" (Bergen et al., 2003). The presence of these three different conditions helps in evaluating the cognitive interference due to the presentation of similar or different bodily effectors in the embodiment process that takes place in the evaluation of the stimulus presented. Thus, the task required a covered embodiment evaluation with visually embodied data, deciding about matching or conflicts due to different actions or different body parts involved.

Before the task, the participants underwent a practice session involving three different figures-verb associations. Afterwards, they received feedback regarding the correctness or incorrectness of the matching. They were trained to respond as quickly as possible to the task. For the task, each participant saw the following in a randomized order: (1) each figure followed by its matching verb once; (2) half of the images followed by a non-matching different effector verb; and (3) half of the images, followed by a non-matching same effector verb. Each figure was presented twice.

2.3 | Procedure

First, each participant was evaluated for inclusion and exclusion criteria. Then they were asked to complete the self-report questionnaires. All participants performed the task on a 17″ laptop (Intel i7, 4.3 GHz, 16 GB RAM). Inpatients were recruited during their first week of admission, while outpatients were recruited during the clinical evaluation period preceding a treatment. The assessment was performed in a quiet room during the morning for all participants.

2.4 | Statistical analyses

Demographic information and body concern scores were evaluated using the Kruskal-Wallis tests with a Bonferroni approach to the post hoc analysis. General linear model (GLM) multivariate analysis has been applied to evaluate differences between subjects, and a GLM for repeated measures was applied to evaluate interactions between task results and diagnosis. Both GLMs applied Bonferroni pairwise post hoc analysis. To evaluate weight recovery efforts, we applied GLM for repeated measures. Weight-recovered patients were compared with the initial (T0) results of AAN and CW with Mann-Whitney analysis due to the different sample sizes. The effect sizes were evaluated with a partial η^2 (η^2_p). Spearman's rank-order correlation was applied to evaluate associations between task results and psychopathological variables. All the analyses were performed using SPSS version 25 software with the alpha set to $p < 0.05$.

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3 | RESULTS

Table 1 summarises the demographic and psychological characteristics of the study samples. At the time of testing, 10 (8.8%) of the 88 patients were on medication with selective serotonin reuptake inhibitors, whereas none of the CW participants were taking medication.

3.1 | Embodiment evaluation

According to the task performance, participants with AN showed the slowest response time across all categories. Moreover, they presented the highest error rate. Participants with AAN showed differences regarding NM-SE responses. See Table 2 and Figure 2 for details. The results were confirmed, excluding participants on medications.

Afterwards, we considered task responses to be a functioning model for an individual's embodiment abilities, evaluating the interaction of diagnosis and task responses in terms of time and correct rates. There was a statistically significant difference in time responses between diagnostic groups (F (4, 280) = 4.518, $p = 0.001$, $\eta^2_p = 0.061$), with differences between AN and CW ($p = 0.002$), AAN and CW ($p < 0.001$), but not between AN and AAN ($p = 0.116$). There was also a statistically significant difference in correct responses between diagnostic groups (F (4, 268) = 3.289, $p = 0.013$, $\eta^2_p = 0.045$), with differences between AN and CW ($p = 0.033$), AAN and CW ($p < 0.001$), but not between AN and AAN ($p = 0.080$).

3.2 | Evaluation after weight recovery

A subsample of 24 patients with AN reached weight recovery at the end of the inpatient treatment (see Todisco, Meneguzzo, Garolla, et al., 2020 for details about the 3-month protocol). These participants were evaluated before being discharged from the residential ED programme, making it possible to evaluate weight recovery as a possible element that might influence the task performance. The subsample was 21.04 ± 5.38 years old, the BMI changed from 15.38 ± 1.57 kg/m^2 at T0 to 19.21 ± 0.78 kg/m^2 before discharge (T1) ($t = -11.165$, $p < 0.001$). Based on the response time, only NM-SE condition significantly reduced following weight recovery ($p = 0.036$). Furthermore, it was only in the match condition that weight-recovered participants showed

TABLE 1 Demographic description of the sample.

	An $n = 45$	AAN $n = 43$	CW $n = 55$	H	p	Post hoc
Age, years	22.29	22.67	23.93	1.656	0.195	
	5.79	5.19	3.16			
BMI, kg/m^2	14.72	20.55	21.65	142.637	<0.001	AN < CW (<0.001)
	1.82	1.18	2.88			A-AN < CW (0.037)
						AN < A-AN (<0.001)
Years of education	16.97	17.15	17.25	0.95	0.823	
	2.25	1.98	1.96			
WP	3.49	3.45	1.14	63.250	<0.001	CW < AN (<0.001)
	1.05	1.59	0.92			CW < A-AN (<0.001)
BIC	3.31	3.34	0.91	77.197	<0.001	CW < AN (<0.001)
	0.96	1.55	0.82			CW < A-AN (<0.001)
A	1.53	1.33	0.29	23.989	<0.001	CW < AN (<0.001)
	1.07	1.24	0.52			CW < A-AN (<0.001)
CSM	2.75	2.51	0.79	44.058	<0.001	CW < AN (<0.001)
	1.29	1.41	0.73			CW < A-AN (<0.001)
D	1.89	2.28	0.38	58.627	<0.001	CW < AN (<0.001)
	0.93	1.30	0.47			CW < A-AN (<0.001)

Note: Means and standard deviations are reported.

Abbreviation: AN: anorexia nervosa, AAN: atypical anorexia nervosa, CW: community women, WP: weight phobia, BIC: body image concern, A: avoidance, CSM: compulsive self-monitoring, D: depersonalisation. Post hoc analysis corrected with Bonferroni method.

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TABLE 2 Comparison of the task results between groups.

	An $n = 45$	AAN $n = 43$	CW $n = 55$	F	$p\ \eta^2_p$	Post hoc
Time						
Match	1065.68	1012.66	797.46	16.307	<0.001	CW < AN (<0.001)
	390.36	169.05	128.46		0.189	CW < A-AN (<0.001)
NM-SE	1175.45	1034.90	865.21	19.490	<0.001	CW < AN (<0.001)
	345.93	189.30	186.73		0.218	CW < A-AN (0.003)
						A-AN < AN (0.027)
NM-DE	1086.40	951.42	815.38	12.668	<0.001	CW < AN (<0.001)
	401.82	197.20	157.60		0.153	CW < A-AN (0.042)
Correct response, %						
Match	85.93	87.40	89.51	6.838	0.001	AN < CW (0.001)
	5.20	4.77	4.68		0.089	
NM-SE	91.76	95.34	96.14	10.767	<0.001	AN < CW (<0.001)
	6.19	4.38	4.00		0.133	AN < A-AN (0.002)
NM-DE	97.22	96.41	98.18	2.159	0.119	
	4.70	5.03	2.86		0.030	

Note: Means and standard deviations are reported.

Abbreviation: AN: anorexia nervosa, AAN: atypical anorexia nervosa, CW: community women. NM-SE: non-matching same effector; NM-DE: non-matching different effector; post hoc analysis corrected with Bonferroni method.

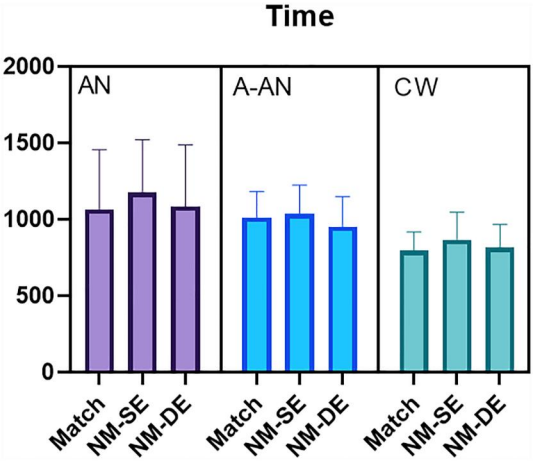

FIGURE 2 Graphical representation of the results showing the distribution of the responding time for each group and condition. Significant differences between groups are reported in the figure with *p*-values.

significantly better performance ($p = 0.007$). See Table 3 for details.

Significant differences were found in most variables comparing CW and weight-recovered AN. In terms of response time, weight-recovered AN patients responded more slowly in all the variables: match ($Z = -4.221$, $p < .001$), NM-SE ($Z = -2.217$, $p = .027$), and NM-DE ($Z = -2.644$, $p = .008$) conditions. In terms of correct responses, a difference was found only for NM-SE ($Z = -1.978$, $p = .048$), while match ($Z = -0.219$, $p = .826$) and NM-DE ($Z = -1.314$, $p = .189$) conditions showed no difference. No significant differences emerged between weight-recovered AN and AAN: time (match, $Z = -1.152$, $p = .249$; NM-SE, $Z = -0.013$, $p = .990$; NM-DE, $Z = -0.406$, $p = .685$) and correct (match, $Z = -1.392$, $p = .164$; NM-SE, $Z = -0.732$, $p = .464$; NM-DE, $Z = -0.171$, $p = .865$).

3.3 | Correlation analysis

Different correlations were found in the subgroups. No significant correlation was found between response times and psychopathological scores. However, there were significant correlations between patients (both AN and AAN) regarding correct responses to the matching tasks and two subscales of BUT, in particular the CSM subscale and correct responses to NM-SE condition and the BIC. See Table 4 for further details.

4 | DISCUSSION

This study evaluated linguistic embodiment abilities in a sample of patients with AN and AAN applying a covered

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TABLE 3 Longitudinal analysis in the AN subsample.

	T0	T1	F	*p* η^2_p
Time				
Match	1077.98	996.23	1.711	0.204
	379.42	193.61		0.069
NM-SE	1114.71	1077.21	4.968	0.036
	326.85	355.45		0.178
NM-DE	1065.40	947.53	1.000	0.328
	375.25	252.59		0.042
Correct response, %				
Match	85.33	88.28	8.666	0.007
	6.37	5.95		0.274
NM-SE	93.05	93.92	1.000	0.328
	4.71	4.91		0.042
NM-DE	97.74	97.92	1.000	0.328
	2.45	2.46		0.042

Note: Means and standard deviations are reported.

Abbreviation: NM-SE: non-matching same effector; NM-DE: non-matching different effector.

task with written verbs and figures of bodily actions, comparing them to a group of control women. Our main hypothesis was that the presence of an impaired difficulties to integrate several bodily information in individuals with AN and AAN resulted in worse performance at a linguistic embodiment task. Our results are in line with this hypothesis—without weight distinction—with a greater interference effect (slower discrimination) in image-word matching tasks, specifically when they are presented in the non-match condition with a shared effector (i.e., action verb and image action depicting a different movement by the same effector). These results lead us to consider the hypothesis that the activation of effector-specific mental representations is a key step in both picture perception and action word retrieval. Moreover, the similar results across the clinical groups and the improvement in the AN subgroup after weight recovery could suggest that weight condition is not the key element in embodied cognition; other elements might play a role in body schema alterations. Indeed, the results of the AN and AAN groups were comparable after weight recovery, showing that differences might be due to psychopathology and body concerns more than weight status.

Previous studies have corroborated the evidence regarding grounding language in sensorimotor experiences (Bergen et al., 2003; Narayan et al., 2004). This is the first study to analyse this specific task comparing clinical and general populations. Our data confirm previous findings of cognitive interference between images and verbs, especially if related to the same effector, calling into a question embodiment cognitive mechanisms. These data are in accordance with the embodied semantic theory, which assumes that different brain networks are involved in perceiving, decoding, and interpreting concrete verbs of body actions (Hauk & Tschentscher, 2013). These effects of language are linked to the visual and written actions and their relationship, showing a specific role of visual representation in the image-processing ability of individuals (Janyan et al., 2011). According to the neuroimaging literature, convergent data have shown the role of the parietal cortex—specifically, the mirror circuits (Péran et al., 2010) and temporal and frontal cortices (Bedny & Caramazza, 2011)—in embodied cognition, with the same brain network activities during mental representation of bodily actions and their real execution (Chaminade et al., 2005). Thus, any delay in response or increase in errors might signal that different cognitive strategies have been applied to perform the task.

A failure of embodied cognition has been proposed to be the background of several emotional disorders (Gjelsvik et al., 2018). Additionally, contemplative mental training has been shown to be an effective way to improve embodied cognition in health subjects (Bornemann & Singer, 2017). Patients with AN required more time to perform the same tasks than CW, showing an impairment that might be linked to the conflicts between bodily integration of body-related stimuli and the disconnection of bodily representations. Impairments in body representation have been shown to be related to errors in the mental evaluation of the space occupied by one's body. Specifically, the parietal networks have been implicated in mentalised body actions (Guardia et al., 2010). Brain networks involved in integrating visuospatial information have been shown to be functionally disrupted in patients with AN (Favaro et al., 2012). Additionally, somatosensory networks (Gaudio et al., 2018) and body processing (Suchan et al., 2013) are impaired in patients with AN.

Our findings corroborate the theory that embodiment could be evaluated as a vulnerability element for AN, and imagery rescripting and imagery-based methods might be valid approaches to modify schemas and body beliefs that interfere with embodied cognition (Tatham, 2011), as preliminary data have already been shown (Pennesi & Wade, 2018). However, more studies are needed, and more attention is required in the treatment pathway due to the connections between embodiment and the emotional-social self (Rossi et al., 2021).

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TABLE 4 Correlation analyses between psychological features and task results.

		BMI	WP	BIC	A	CSM	D
Anorexia nervosa							
Time	Match	−0.084	0.098	−0.086	0.071	−0.010	0.035
	NM-SE	−0.268	0.127	−0.068	0.100	−0.052	0.111
	NM-DE	−0.109	0.027	−0.106	−0.009	−0.124	0.025
Correct response	Match	0.017	0.100	−0.086	0.060	0.310*	0.201
	NM-SE	0.099	−0.077	−0.398**	0.119	−0.007	−0.037
	NM-DE	0.139	0.096	−0.100	−0.224	−0.064	−0.128
Atypical anorexia nervosa							
Time	Match	0.162	−0.111	−0.050	0.300	0.015	−0.132
	NM-SE	0.171	−0.206	−0.091	0.194	−0.037	−0.033
	NM-DE	0.247	−0.197	−0.181	−0.174	−0.169	−0.263
Correct response	Match	−0.356*	0.058	−0.077	0.242	0.341*	0.123
	NM-SE	−0.255*	−0.465**	−0.435**	−0.045	−0.243	0.043
	NM-DE	−0.608**	−0.013	−0.165	−0.268	0.079	0.101
Community women							
Time	Match	−0.181	0.072	0.076	0.071	0.085	0.262
	NM-SE	−0.230	−0.031	0.030	0.041	0.128	0.225
	NM-DE	−0.166	−0.020	0.037	0.058	0.087	0.162
Correct response	Match	0.024	0.008	−0.073	0.041	0.024	−0.174
	NM-SE	0.069	−0.250	−0.184	−0.343*	−0.231	−0.406**
	NM-DE	0.113	0.074	0.128	0.132	0.147	0.025

NM-SE: non-matching same effector; NM-DE: non-matching different effector, WP: weight phobia, BIC: body image concern, A: avoidance, CSM: compulsive self-monitoring, D: depersonalisation.

*, $p < 0.05$; **, $p < 0.001$.

Looking at correlations between body psychopathology and embodiment, results have to be confirmed with further studies but connections with body image concerns could reveal specific areas of intervention. In the CW group, we found a specific negative connection between avoidance, depersonalisation, and the ability to correctly identify unmatched pairs with the same effector. This finding is in line with the theory that embodiment comes from a highly cognitive integration of bodily information, body schema, and body image (Winkielman et al., 2015). In the clinical population, a positive correlation was reported between AN and AAN concerning correct responses at match pairs and compulsive self-monitoring. This finding corroborates the central role that correct integration of bodily information with body image plays in AN. Correct integration has also been proposed as a psychological trait in AN, although further studies are needed (Jenkinson et al., 2018; Meneguzzo et al., 2022; Monteleone et al., 2021).

When the task presents a different action for the same body effector (NM-SE), AN and atypical AN participants reported negative correlations with body image concerns. This result might be related to a cognitive rumination about the body that could interfere with the ability to discriminate actions from the same body parts when there is a high level of bodily rumination. Although only future investigations can corroborate this hypothesis. Finally, only participants with AAN reported negative correlations between BMI and correct responses, indicating that a lower weight (but not underweight) might help people with AN to correctly discriminate embodiment tasks. These results reveal the peculiar relationships between embodiment and cognitive functioning in AN, calling for more specific investigations.

Moreover, there is evidence that embodiment plays a role in social cognition (Gallese et al., 2007) and self-identity (Rajan-Rankin, 2014). The emotional and cognitive self is linked to embodiment processes because

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they share body representation (De Vignemont, 2011) with the mediation of interoception (Gao et al., 2019). All these aspects play a role in the linguistic representation and the current discussion about the linguistic representation of our body, which is overcoming the traditional dualistic contraposition between body and mind (Lindblom, 2020). Anorexia nervosa has been described as a disorder characterised by a "lost" emotional self, with interoceptive difficulties and social cognition impairments (Meneguzzo et al., 2020, 2022; Oldershaw et al., 2019)Embodied cognition might play a key role in understanding the relationships between body and mind in the future. However, these are also characteristics that an improvement in embodied cognition might modify. An evaluation of cognitive treatments of embodiment is currently missing in the literature.

4.1 | Limitations

The current study has several limitations. This was the first application of this task in a clinical population, the results need replication, and further research is needed to corroborate its validity. Moreover, we should consider that there might be a retest-related learning bias. However, the exposure time to the pictures, the time interval between test and retest, and the randomisation of the task might allow us to exclude a learning bias cautiously—even if future studies should also evaluate this aspect. Other limitations of the study to consider are the sample size and the inclusion of patients with different illness duration and ages. Finally, we included only females, thus reducing the possibility of generalising the results, and we evaluated only one aspect of embodied cognition. For these reasons, future studies should evaluate various aspects, confirming results with larger samples, considering illness duration and age as differentiating elements, and looking at specific ones that might become treatment targets.

4.2 | Conclusion

This study has evaluated linguistic embodiment in clinical population for the first time. The task applied evaluated the ability of individuals with AN and AAN to associate visual and written bodily actions and differentiate between different effectors. The data show the presence of an impairment in patients compared to community peers, corroborating the hypothesis that patients with AN exhibit a compromised ability to integrate body information.

AUTHOR CONTRIBUTIONS

Conceptualisation: Paolo Meneguzzo, David Dal Brun, Elena Tenconi, and Angela Favaro; Data curation: Paolo Meneguzzo; Formal analysis: Paolo Meneguzzo; Funding acquisition: Patrizia Todisco and Angela Favaro; Investigation: Paolo Meneguzzo, Valentina Meregalli, Enrico Collantoni, and David Dal Brun; Methodology: Paolo Meneguzzo, Enrico Collantoni and Valentina Meregalli; Project administration: Angela Favaro; Resources: Patrizia Todisco; Software: Paolo Meneguzzo, David Dal Brun, and Elena Tenconi; Supervision: Patrizia Todisco, Elena Tenconi, and Angela Favaro; Writing – original draft: Paolo Meneguzzo, Enrico Collantoni, Valentina Meregalli, and David Dal Brun; Writing – review and editing: Patrizia Todisco, Elena Tenconi, and Angela Favaro. All authors have read and agreed to the published version of the manuscript.

ACKNOWLEDGEMENTS

This work was supported by the 'Department of excellence 2018-2022' initiative of the Italian Ministry of education (MIUR) awarded to the Department of Neuroscience—University of Padua.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The datasets used and analyzed during the current study are available from the corresponding author upon reasonable request.

ORCID

Paolo Meneguzzo https://orcid.org/0000-0003-3323-6071
David Dal Brun https://orcid.org/0000-0003-0693-5520
Enrico Collantoni https://orcid.org/0000-0002-6730-1778
Valentina Meregalli https://orcid.org/0000-0003-0016-1237
Patrizia Todisco https://orcid.org/0000-0002-2212-9855
Angela Favaro https://orcid.org/0000-0002-6540-5194
Elena Tenconi https://orcid.org/0000-0003-1629-9871

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How to cite this article: Meneguzzo, P., Dal Brun, D., Collantoni, E., Meregalli, V., Todisco, P., Favaro, A., & Tenconi, E. (2023). Linguistic embodiment in typical and atypical anorexia nervosa: Evidence from an image-word matching task. *European Eating Disorders Review*, 1–13. https://doi.org/10.1002/erv.3008

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