Out of body, out of space: Impaired reference frame processing in eating disorders

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Out of body, out of space: impaired reference frame processing in eating disorders

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Highlights

- A distorted body representation is a core and persistent symptom in EDs.
- Our data suggests an impairment in the processing of reference frames in EDs.
- ED patients may be locked to an allocentric representation of their own body.
- This impairment may be related to the pathophysiology of EDs.

Abstract

A distorted body representation is a core symptom in eating disorders (EDs), though its mechanism are unclear. Allocentric Lock Theory, emphasizing the role of reference frame processing in body image, suggested that ED patients might be locked to an allocentric representation of their own body. Comparison of ED and healthy participants on allocentric retrieval and its update suggests an impairment in the processing of reference frames that may be related to the pathophysiology of EDs.

Keywords: *Eating Disorders; Body Image; Spatial Reference Frame*

Introduction

A distorted body representation (i.e., body size over-estimation) is a core and persistent symptom in Anorexia Nervosa (AN) and Bulimia Nervosa (BN) with important prognostic value, though the nature of this bias is still unclear (Mohr et al., 2011; Mohr et al., 2010; Riva, 2012, 2014; Riva and Gaudio, 2012; Riva et al., 2015).

Evidence from neuroscience indicates that spatial experience, including the bodily one, involves the continuous interaction of two different spatial representations, defined on the basis of the reference frame used to encode and store information (Burgess, 2006; Burgess et al., 2001)- "*the egocentric*" that codes and updates information (i.e., body as the reference point of first-person experience), and "*the allocentric*", responsible for the long-term storage of information (i.e., environmental features as reference points with the body as an object similar to others in the physical world). Driven by and building on this evidence, the Allocentric Lock Theory (ALT)(Riva, 2012, 2014; Riva and Gaudio, 2012) emphasizing the role of spatial reference frame processing in body image, suggests that, in eating disorders (EDs), the way the body is "experienced" and "remembered" may be affected. Specifically, according to ALT, the process involving the continuous interaction of two different spatial representations may be impaired in EDs (Riva, 2012, 2014; Riva and Gaudio, 2012).That is, ED patients may be locked to an allocentric representation of their own body (i.e., abstract knowledge, beliefs and attitudes related to the body) since the egocentric representations, driven by perceptual inputs, are unable to update its contents.

We compared the performances of ED patients and healthy controls (HCs) on five standard spatial abilities (neuropsychological measures), allocentric retrieval, and its update following perceptual inputs [experimental Virtual Reality (VR)-based procedure] with the aim of investigating potential impairments in spatial reference frame processing in EDs.

Methods

A total of forty-four volunteering women, recruited from the waiting list of an Italian ED specialist centre and an ED research database at Catholic University in Milan, participated in the study, including 22 with an ED (50% AN, 50% BN) and 22 HCs matched for sex, age, race/ethnicity, language, and education. Gold standard diagnostic tools [i.e., the Structured Clinical Interview for DSM-IV-TR Axis I Disorders (First et al., 2002), the Eating Disorder Examination-Interview-16.0D (Fairburn et al., 2008)] were administered to assess participants and ensure that they met the study eligibility criteria in order to allocate them to the appropriate group (detailed information are given in eTable in the supplement). Demographic and clinical characteristics are reported in Table.

Five standard neuropsychological measures were used in the evaluation of spatial abilities. Specifically, the Corsi Block Test- Span (Corsi, 1972), the Corsi Block Test- Supraspan (Corsi, 1972), the Money Road Map (Money et al., 1965), the Manikin's Test (Ratcliff, 1979), and the Judgment of Line Orientation (Benton et al., 1978) were used to assess short-term spatial mnestic abilities, long-term spatial mnestic abilities navigation abilities, mental rotation abilities, and visuo-spatial abilities, respectively. State and trait anxiety levels were assessed in all participants[1] using the brief version of State-Trait Anxiety Inventory (Tluczek et al., 2009)to rule out the possibility that differences in the performances of ED and HC controls on spatial abilities, allocentric retrieval, and its update following perceptual inputs (experimental VR-based procedure; see below) could be due to anxiety (Riva, 2014; Robinson et al., 2013).

After administration (in counterbalanced order) of the above measures, a VR-based

[1] As trait and state anxiety did not differ across study groups (see Table), they were not used as covariates in our planned analyses.

procedure (consisting of an encoding phase, followed by a retrieval phase in two different counterbalanced tasks) was initiated. Specifically, after an initial training in VR technology, all participants were invited to retrieve the position of a hidden object they had discovered in the virtual city and memorized (*encoding phase*) on a map – a full aerial view of the virtual city (*Task 1*), and to indicate the position of that object (which was absent) entered in the virtual city from another starting point (*Task 2*). While *Task 1* ("allocentric retrieval") required and measured the ability to retrieve an allocentric viewpoint-independent representation (i.e., a retrieval with spatial allocentric information independent of point of view), *Task 2* ("allocentric updating") assessed the ability to change this stored long-term representation following perceptual inputs (i.e., a retrieval without any visible spatial allocentric information independent of point of view). Detailed information on the development of the VR-based procedure, the spatial location accuracy (dependent variable), defined as the difference between the correct and the estimated positions of the hidden object, as well as on the aforementioned standard neuropsychological measures, are available at http://www.neurovirtual.eu/clinical-protocols.html.

Differences between ED and HC groups in neuropsychological measures (two-sample *t*-test) and spatial location accuracy for both VR-based tasks (repeated measures ANOVA with "task" as within-subjects variable) were computed in SPSS 22.0 (IBM Corp, NY).

All participants provided written informed consent. The Ethics Committee of Catholic University approved the study.

Results

ED patients, relative to HCs, displayed significantly poorer visuo-spatial, navigation, mental rotation, and, short and long-term spatial mnestic abilities (Table), with greater deficiencies in the allocentric "retrieval" and "updating". Specifically, results revealed that the main effect of "group" (but not of the "task") was significant [$F(1, 42) = 8.99$, $p < .01$, $\eta_p^2 = 0.17$]. Specifically, the ED group reported significantly weaker abilities in retrieving the position of the hidden object in both VR-based tasks [Task-1: 0.27 (SD = 0.23) and Task-2: 0.25 (SD = 0.27)] than the HC group [Task-1: 0.13 (SD = 0.17) and Task-2: 0.10 (SD = 0.10)].[2]

[Insert Table about here]

Discussion

Beyond impairments in visuo-spatial, navigation, mental rotation and short and long-term spatial mnestic abilities, our results revealed that ED patients were significantly less accurate in retrieving the position of the memorized object, which requires the ability to construct an allocentric viewpoint-independent representation (VR-based Task 1), and their ability to refer to this stored long-term representation and change it according to perceptual inputs (VR-based Task 2), relative to HCs.

It is still controversial if body representation disturbances in EDs are secondary to biological dysfunctions in the ventral and dorsal neural circuit (Kaye et al., 2009) or reflect a primary disturbance in the way the body is "experienced" and "remembered" (Riva, 2012, 2014; Riva and Gaudio, 2012). Our findings suggest the existence of a primary impairment in the processing of spatial reference frames in ED patients, that may be related to the pathophysiology of these disorders, involving ALT. EDs may be associated with an impairment in the ability of updating a negative body representation stored in allocentric memory (e.g., "My body is fat")

[2] Controlling for body mass index or standard spatial abilities (Table) using ANCOVA(s) findings did not change. In addition, exploratory analyses comparing AN and BN subgroups with HCs were consistent with those of EDs vs. HCs, suggesting that it was unlikely that the differences found were driven by one ED subgroup.

with real-time contrasting egocentric sensorimotor and proprioceptive data (Riva, 2012, 2014; Riva and Gaudio, 2012).

Our findings are also consistent with recent fMRI studies revealing a dysfunction in parietal cortex in AN and BN patients (Mohr et al., 2011; Mohr et al., 2010), which is a critical area for the integration of egocentric representations and processing of body image (Riva, 2014) Further, adequately powered research over different phases of an ED, is needed to support the tenets of ALT and the role of spatial reference frame processing in the pathophysiology of EDs. With further investigations, our findings, can contribute to our understanding of the underlying bases of body representation disturbance in EDs, suggesting an impairment in the allocentric retrieval and updating of spatial information, which is vital for improving current prevention and treatment approaches (Treasure et al., 2010).

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Authors' Contribution

G. Riva and S. Serino developed the study concept. All authors contributed to the study design. S. Gaudio, A. Dakanalis and S. Serino were involved in the data collection. A. Dakanalis and S. Serino performed the data analysis and interpretation under the supervision of G. Riva. A. Dakanalis and S. Serino wrote the first draft of the manuscript. G. Riva, G. Carrà, M. Clerici, S. Gaudio, P. Cipresso were involved in a critical revision of the manuscript for important intellectual content. All the authors approved the final version of the manuscript for submission.

Declaration of Conflicting Interests

The authors declare that they have no conflict of interest.

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Table

Table. Demographics, clinical details, and performance of participants with an eating disorder and of healthy controls on spatial abilities

5. Table(s)

Table. Demographics, clinical details, and performance of participants with an eating disorder and of healthy controls on spatial abilities[a]

Characteristic	Eating Disorders *M* (SD)	Healthy Controls *M* (SD)	Comparison *p*-test
Age, y	29.59 (11.06)	30.05 (11.30)	-.134
Education, y	14.98 (3.87)	16.64 (2.79)	-1.62
Duration of illness, y	7.50 (2.11)	-	-
Body shape/size concern[a,b]	4.54 (0.46)	0.76 (0.46)	27.55[d]
Weight concern[a,b]	4.50 (0.59)	0.75 (0.57)	21.26[d]
Overall eating psychopathology[a,b]	4.53 (0.31)	0.46 (0.28)	46.00[d]
Body Mass Index (BMI)[c]	21.24 (5.08)	21.31 (2.79)	-0.52
Trait anxiety	12.04 (2.38)	11.54 (2.59)	0.66
State anxiety	8.72 (0.95)	8.72 (2.81)	-0.07
Short-term spatial memory	5.06 (0.74)	6.19 (0.87)	-4.62[d,e]
Long-term spatial memory	19.07 (5.14)	25.07 (2.42)	-4.88[d,e]
Navigation abilities	24.05 (6.12)	29.36 (4.15)	-3.37[d,e]
Mental rotation abilities	28.91 (6.07)	31.57 (1.30)	-2.01[e,f]
Visuo-spatial abilities	22.18 (5.38)	25.90 (3.37)	-2.74[d,e]

[a] Assessment with "gold" standard diagnostic tools allowed allocation of participants to the appropriate group (see eTable in the supplementary material); all participants were female and native Italian speakers of Caucasian race/ethnicity.
[b] A cut-off score of ≥ 4 is a marker of clinical significance (see eTable).
[c] Anthropometric measurements were made and BMI (kg/m^2) was calculated (see TableS1). In keeping with the ED diagnosis, the AN patients had a lower mean BMI (16.69, SD = 3.51) as compared with that of BN patients (23.90, SD = 5.12, $t_{20} = -3.85$, $p < .01$). Although there were not significant differences in BMI between BN patients and HCs ($t_{31} = 1.89$, $p > .05$), the AN patients had also a lower mean BMI as compared with that of HCs ($t_{31} = -4.11$, $p < .001$).
[d] df = 42; P < .001; large effect size (Cohen's $d \geq .80$)
[e] Controlling for BMI, using ANCOVA did not change the reported findings regarding group differences on spatial abilities.
[f] df = 42; P< .05; medium effect size (Cohen's $d \geq .50$)

7. Optional e-only supplementary files

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