AUTHOR QUERY FORM

ELSEVIER	**Journal: YMEHY** **Article Number: 6692**	**Please e-mail or fax your responses and any corrections to:** **E-mail: corrections.eseo@elsevier.sps.co.in** **Fax: +31 2048 52799**

Dear Author,

Please check your proof carefully and mark all corrections at the appropriate place in the proof (e.g., by using on-screen annotation in the PDF file) or compile them in a separate list. Note: if you opt to annotate the file with software other than Adobe Reader then please also highlight the appropriate place in the PDF file. To ensure fast publication of your paper please return your corrections within 48 hours.

For correction or revision of any artwork, please consult http://www.elsevier.com/artworkinstructions.

Any queries or remarks that have arisen during the processing of your manuscript are listed below and highlighted by flags in the proof. Click on the 'Q' link to go to the location in the proof.

Location in article	Query / Remark: click on the Q link to go Please insert your reply or correction at the corresponding line in the proof
Q1	Please confirm that given names and surnames have been identified correctly.
Q2	Please provide a complete affiliation for a, b, c.

Please check this box if you have no corrections to make to the PDF file ☐

Thank you for your assistance.

Medical Hypotheses xxx (2012) xxx–xxx

Contents lists available at SciVerse ScienceDirect

Medical Hypotheses

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

Allocentric lock in anorexia nervosa: New evidences from neuroimaging studies

Giuseppe Riva [a,b,*], Santino Gaudio [c]

[a] Istituto Auxologico Italiano, Milan, Italy
[b] Università Cattolica del Sacro Cuore, Milan, Italy
[c] Università Campus Bio-Medico, Rome, Italy

ARTICLE INFO

Article history:
Received 6 January 2012
Accepted 30 March 2012
Available online xxxx

ABSTRACT

Individuals with anorexia nervosa (AN) have a disturbance in the way in which their body is experienced and tend to evaluate negatively their own body and body parts. It is controversial whether these symptoms are secondary to dysfunctions in the neuronal processes related to appetite and emotional regulation or reflect a primary disturbance in the way the body is experienced and remembered.

According to the "Allocentric Lock Hypothesis – ALH" (http://dx.doi.org/10.1016/j.mehy.2011.10.039) individuals with AN may be locked to an allocentric (observer view) negative memory of the body that is no more updated by contrasting egocentric representations driven by perception. Recent neuroimaging studies are showing several structural and functional alterations in frame- and memory-related body-image-processing brain circuits that may support ALH.

Body image disturbances are at the core of anorexia nervosa (AN): individuals with AN have a disturbance in the way in which their body is experienced and tend to evaluate negatively their own body and body parts (Table 1).

However it is not yet clear the role of these disturbances in the etiology of AN. It is controversial whether these symptoms are secondary to dysfunctions in the neuronal processes related to appetite and emotional regulation or reflect a primary disturbance in the way the body is experienced and remembered.

In their recent review, Kaye et al. [1] support the first hypothesis. According to them AN is the outcome of an impairment in the modulation of reward and emotion in response to appetitive stimuli. In this view the negative affect—such as anxiety and harm avoidance—is the result of problems in accurately coding or integrating positive and negative emotions within ventral striatal circuits. More, body image disturbances may be produced by dysfunctions in the ventral (limbic) neurocircuit that includes the amygdala, insula, ventral striatum and ventral regions of the anterior cingulate cortex and the orbitofrontal cortex. Specifically, they suggest that the altered activity in the anterior insula found in individuals with AN [2,3] and the role of the insula in integrating interoceptive information [4] might underlie a physiologically altered sense of self and a distorted body image.

This review focuses on another perspective: the "Allocentric Lock Hypothesis – ALH" [5,6]. This theory suggests that AN may be the outcome of a primary disturbance in the way the body is experienced and remembered: individuals with AN may be locked to an allocentric (observer view) negative memory of the body that is no more updated by contrasting egocentric representations driven by perception.

New brain imaging studies are showing several structural and functional alterations in memory- and frame-related body-image-processing brain circuits in individuals with AN, suggesting their potential role in the appearance of the disturbance.

This review integrates findings from neuroimaging studies to support this hypothesis and to explain its possible role in the etiology of AN.

Reference frames in the bodily experience

A "reference frame" is a representation used by our brain to convey the layout of points in space [7]. The literature about spatial cognition identifies two different reference frames [8–10] that are the result of the integration of different sensory inputs (Fig. 1): *egocentric* (it conveys the positions of points using the body as the center of the surrounding space) and *allocentric* (it conveys the positions of points using external landmarks).

The ability of representing and recalling an object, including our own body, changes according to the used frame: when we adopt an egocentric stance we represent the object relative to ourselves; when we adopt an allocentric stance the object is represented independently of our own current relation with it [8,11].

Recently Zaehle et al. [9] explored the functional and anatomical underpinnings of egocentric and allocentric coding of spatial coordinates. Specifically, they identified a bilateral

* Corresponding author. Address: Applied Technology for Neuro-Psychology Lab, Istituto Auxologico Italiano, Via Ariosto 13, 20145 Milan, Italy. Tel.: +39 02 619112726; fax: +39 02 6191127892.
E-mail addresses: giuseppe.riva@unicatt.it (G. Riva), santino.gaudio@libero.it (S. Gaudio).

0306-9877/$ - see front matter © 2012 Published by Elsevier Ltd.
http://dx.doi.org/10.1016/j.mehy.2012.03.036

Table 1
DSM-IV-TR, diagnostic criteria for anorexia nervosa.

307.1 Anorexia Nervosa
- Refusal to maintain body weight at or above a minimally normal weight for age and height, for example, weight loss leading to maintenance of body weight less than 85% of that expected or failure to make expected weight gain during period of growth, leading to body weight less than 85% of that expected
- Intense fear of gaining weight or becoming fat, even though underweight
- Disturbance in the way one's body weight or shape is experienced, undue influence of body weight or shape on self evaluation, or denial of the seriousness of the current low body weight
- In postmenarcheal females, amenorrhea, i.e., the absence of at least 3 consecutive menstrual cycles. A woman having periods only while on hormone medication (e.g. estrogen) still qualifies as having amenorrheaThere are two types of anorexia nervosa
  (1) Restricting type, in which the person has not regularly engaged in binge-eating or purging behavior
  (2) Binge-eating/purging type, in which the person has regularly engaged in binge-eating or purging behavior (that is, self-induced vomiting or the misuse of laxatives, diuretics or enemas)

Fig. 1. Egocentric and allocentric representation of space. The egocentric representation (on the left, Times Square image taken from Google Maps Street View, © 2012 Google) integrates perceptual impressions gathered from a first-person perspective relative to the position and heading (front–back, right–left, and up–down) of the subject. The egocentric frame is referred to the body of the observer and allows him/her to locate objects relative to the body centre: within this frame the position of an object changes if the subject moves. The allocentric representation (on the right, Times Square image taken from Google Maps Satellite View, © 2012 Google BlueSky DigitalGlobe GeoEye) instead establishes a "map" with an origin and a reference direction external to the subject. The allocentric frame is referred to space external to the perceiver: within this frame the position of an object does not change if the subject moves. These two frames have different sources. The egocentric frame has its primary source in *somatoperceptions*: representations of the present state of the body and tactile stimuli from sensory inputs. The allocentric frame has its primary source in *somatorepresentations*: abstract knowledge, beliefs, and attitudes related to body as an object of third-person perception, categorization, and cognitive reflection.

fronto-parietal network including the superior occipital gyri, the superior parietal lobe (precuneus), the anterior part of the calcarine sulci, the superior frontal gyri, the left inferior temporal gyrus and the inferior parietal lobe. Furthermore, they identified separate neural circuits mediating the two spatial coding strategies, involving additional cortical and subcortical areas. The egocentric frame is mainly associated with precuneus activation (even though this region is part of the common network); this data was previously reported in the studies of Committeri et al. [10] and Galati et al. [12]. The allocentric frame recruits right-sided parietal areas, the bilateral ventral visual stream, and the hippocampal formation [9]. An Hippocampal activation was also found comparing allocentric and egocentric spatial memory in healthy individuals by Parslow et al. [13]. Galati et al. showed that allocentric coding activates a posterior parietal region, located in the parietal lobule and the intraparietal sulcus [12].

Finally, an enhanced activation of the right Extrastriate Body Area – EBA was found in the allocentric perspective compared to the egocentric prospective of bodies [14] or body parts [15]. However, it is still not clear whether the EBA is involved in the identification of one's own body and bodies of others [16] or not [17].

In sum, the two frames of reference for their processing require the involvement of partly distinct brain regions [9]. On one side, information related to the egocentric frame of reference is processed by medial superior–posterior areas, On the other side, the processing related to the allocentric frame of reference involves also the ventral visual stream, the right parietal cortex and the hippocampal formation. In other words, the egocentric processing requires only a part of the neural circuits involved in the processing of the allocentric spatial coding.

Reference frames in autobiographical memory

The two spatial reference frames play a critical role, too, in autobiographical memory. In fact it is possible to remember the spatial features of an autobiographic event – e.g., a mountain hike (Fig. 2) – using an egocentric or allocentric view point [11,18,19]: the rememberer may "see" the event from his or her perspective as in normal perception (*field mode*), or "see" the self engaged in the event as an observer would (*observer mode*).

As shown by different authors, autobiographic memory recall requires the involvement of a network that includes prefrontal regions, visual and parahippocampal regions, and the hippocampus [20–23]. Recently, Eich et al. [24] explored the functional and anatomical underpinnings of field and observer coding of spatial memory. Their data are consistent with the above studies on autobiographic memory, although some subsystems differ when retrieval perspective is required. Specifically, the bilateral insula, left somatosensory areas, and the right posterior dorsal amygdala have a different involvement according to the specific coding required: in field coding both the somatosensory regions and the right amygdala increased their activity; in observer coding both the insula regions and somatosensory regions decreased their activity.

Different authors suggested that anxiety may have a role in the encoding of autobiographic memories in observer mode [25]. Anxious subjects tend to evaluate specific situations as being excessively dangerous. When this happens, they shift attention away from the situation and become highly self-focused seeing themself as if from an external point of view [26]. Research by Wells & Papageorgiou [27] showed that, in recalling anxiety-provoking social situations, individuals with social phobia and agoraphobia are

Please cite this article in press as: Riva G, Gaudio S. Allocentric lock in anorexia nervosa: New evidences from neuroimaging studies. Med Hypotheses (2012), http://dx.doi.org/10.1016/j.mehy.2012.03.036

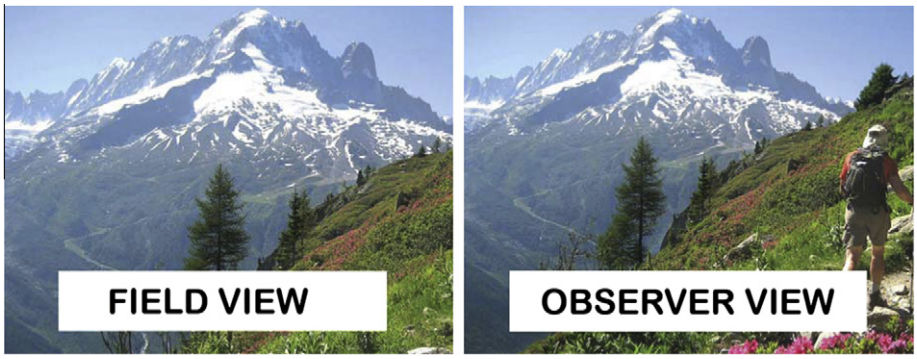

Fig. 2. Field and observer modes in episodic memory. In field mode the subject remembers the view of the Mont Blanc from his mountain hiking through the subject's own eyes, as if he were looking outward (on the left). In the observer mode the subject remembers the view of the Mont Blanc including him as an actor in the memory image (on the right).

more likely to take an observer perspective whereas control subjects are more likely to take a field perspective. A similar result was obtained by Osman and colleagues [28] in a sample of patients with body dysmorphic disorder.

Other authors suggest that culture, too, may have a role in the observer encoding, especially for females. As underlined by Blood [29] in our culture "a woman's body is viewed as a biological object separate from the individual who perceives her body. It is assumed that a woman should be able to perceive her own body objectively and (more or less) accurately in the same way that she might perceive the dimension of an animate object, such a vase" (p. 2). For this reason, women are taught to disembody themselves (*self-objectification*), considering their body as an object they look at [30].

The experience of the body in autobiographical memory

As underlined by the "embodied cognition" approach, remembering a personal event can be considered an embodied simulation in which individuals re-experience similar visual, spatial, affective and kinaesthetic contents that were part of their original experience [31,32]. More, the contents of a remembered event are stored in the perceptual and motor pathways that were involved in the processing of the event [33].

As we have seen, in observer mode, autobiographical memories include also the body of the subject. And different studies underline the importance of sensory and motor functions in memory retrieval. For example, posture [34] and facial expression [35] congruent with the encoding context facilitate recall of information or autobiographical memories.

An interesting issue for our discussion is the following: how does an allocentric experience of the body, integrated in autobiographic memory, interact with the egocentric real-time experience of the same body?

Byrne et al. [18,36] suggest that short-term retention of perceptual information is achieved by egocentric representations that match the location and configuration of the body. By contrast, long-term memory for locations is achieved by allocentric representations because the location and configuration of the body during retrieval will be usually different. Within this model, the translation between the allocentric and the egocentric representations is performed by a specific transformation circuit, assumed to be in the retrosplenial cortex/intraparietal sulcus. Specifically, the circuit calculate the distance and bearings in allocentric coordinates by combining the head direction with information about the distances and egocentric bearings of local surfaces. But what does it happen if for some reasons this process is impaired?

The impairments in autobiographical memory found in patients with damage involving the retrosplenial cortex [37] suggest that a problem in the translation circuit may disrupt the retrieval and/or update of stored memories. On one side, if the allocentric/egocentric transformation is impaired the subject is not able to retrieve the contents of the allocentric memory (retrograde amnesia) [38]. On the other side, if the egocentric/allocentric transformation is impaired the subject is not able to update the contents of the allocentric memory. This is what apparently happens in anorexia nervosa [5]: an altered memory of the body – that is not modified by contrasting egocentric parietal representations driven by perception [39] – primes the processing of any further body-related experience [40]. In simpler words, the anorectic individual is locked to an allocentric (*observer view*) negative representation of her/his body [5,6,41].

Neural bases of an unbalanced relationship between the allocentric/egocentric reference frames in AN

Neuroimaging studies on AN patients showed several structural and functional alterations and some of these alterations involve some of the key regions of the egocentric/allocentric reference frames. Regarding the core regions of both reference frames, alterations were found in the inferior parietal lobe activity in EDs patients using different tasks: photographs of one's own body [16]; line drawings of underweight, normal weight and overweight female body shapes [42]; own distorted body image [43]. Moreover, gray matter alterations were found in the inferior parietal lobe both in patients with AN restrictive type who have a disease duration less than 1 year [44,45], and in those with disease duration longer than 1 year [46]. Regarding the egocentric reference frame, Mohr et al. [47] revealed that in the AN subjects a modulation of the precuneus activity is absent during body size estimation, while healthy subjects demonstrated a linear modulation of the precuneus activity by the distortion levels of the self-images during the body size estimation. Vocks et al. [16] found that AN patients, after body image therapy, looking at their own body images, showed increased activation of the extrastriate body area and decreased activation in the left precuneus, the right inferior and superior frontal gyri, the bilateral inferior parietal lobule, the left posterior cingulate gyrus, the left fusiform gyrus and the right parahippocampal gyrus. Interestingly, a high concordance exists among different structural neuroimaging studies on the presence of a specific GM decrease of the precuneus in AN patients. This alteration was revealed in AN patients who have a disease duration less than 1 year [44,45], and in those with disease duration longer than 1 year [46] and in those recovered from anorexia for over 5 years [48]. Regarding the allocentric reference frame, Connan

Please cite this article in press as: Riva G, Gaudio S. Allocentric lock in anorexia nervosa: New evidences from neuroimaging studies. Med Hypotheses (2012), http://dx.doi.org/10.1016/j.mehy.2012.03.036

et al. [49] found a significant reduction in hippocampal volume (−8.2% right; −7.5% left) in AN patients and Giordano and colleague (2001) found a significant volume reduction of the amygdala–hippocampus complex. However, structural studies, which used a Voxel Based Morphometry (VBM) analysis, found no hippocampal alteration in AN patients compared to healthy subjects [44–46].

These evidences may indicate a dysfunction of the egocentric/allocentric reference frames, with a main specific involvement of the precuneus and the inferior parietal lobe. The first area is principally implicated in egocentric frame reference, even though it is one of the core regions of both frames as the second area (the inferior parietal lobe). The precuneus and the posterior parietal cortex are related to the multimodal coding of body schema [50] and alterations in these areas have been found to be associated with distortions in spatial body relationships and motor behavior [51]. The integrity of the function of precuneus seems to be essential for self-reference [52]. More, the inferior parietal lobe is involved in self body identification [17,53]. We could suppose that the presence of alterations in the precuneus and the inferior parietal lobe can produce an unbalanced relationship between the two frames in AN patients, with a prevalence of the allocentric frame that leads to a distorted body size estimation, related to an inadequate somatosensorial updating.

In other words, as predicted by ALH, AN individuals may be locked to an allocentric negative representation of their body, that they are not able to modify even after dramatic body changes [5,41].

Allocentric lock and eating disorders

Other authors identified in the past a possible cause of AN in a distorted body image that drives behavior and influences information processing (cognitive bias) [54–56]. However, ALH has some advantages: (a) it identifies the source of the bias in a specific cognitive process – the egocentric-allocentric transformation in spatial cognition; (b) AN are not caused by the bias alone (necessary but not sufficient condition), but also by (i) the impossibility for the person of modifying the bias (allocentric lock); (ii) the cultural suggestion of addressing the negative emotions related to the bias through eating control.

Implications for treatment

From a clinical viewpoint ALH suggests that an important goal for the treatment of AN is the unlocking and update of the allocentric negative body image. Unfortunately, this goal is not shared by the existing therapies for this disturbance. As noted by Rosen 15 years ago – but the situation is not changed so much yet – only 1/3 of cognitive-behavioral treatments assessed in his review addressed body image specifically [57]. And when it happens, the focus is more on shape concerns and over-evaluation than on the experience and perception of a fat body [58]. During the last decade, however, virtual reality (VR) emerged as a technology that is especially suitable for the treatment of body image [59]. Ferrer-Garcia and Gutiérrez-Maldonado conclude their recent review about the use of VR for the assessment and treatment of body image in eating disorders with the following words [59]: "Several conclusions can be drawn from reviewed studies. VR-based therapies seem to be especially suitable for improving body image both in ED patients and in subclinical samples... All these studies showed significantly greater improvement in measures related with body image when the VR component was added." (p. 9). A possible explanation for these effects comes from an experiment from Burgess and colleagues [60]. They assessed in a VR experiment the neural systems involved in the retrieval of the spatial context of an event. The measured activation showed the buffering of the location of scene elements in successively translated frames of reference (allocentric, body-centered, head centered) between the parahippocampus and the precuneus.

Their data and the clinical data apparently suggest that VR may induce a controlled sensory rearrangement that facilitates an update of the locked allocentric representation of the body [41]. Obviously further controlled studies, comparing VR-based treatments with traditional ones, are required to test the real efficacy of this approach.

Conclusions and future directions

This review suggests that spatial experience of one's own body is incorrectly processed in people with AN producing a distorted body image representation. Particularly, AN patients seems to show an impaired egocentric/somatosensorial updating, that can be explained by the brain alterations revealed in the key areas of both the core regions of the allocentric/egocentric frames and the core region of the egocentric frame (i.e. the precuneus and the inferior parietal lobe). The final outcome – an allocentric negative representation of their body, that cannot be updated – is coherent with the predictions of the Allocentric Lock Hypothesis suggesting that AN may be the outcome of a primary disturbance in the way the body is experienced and remembered. Adolescence is a crucial time of the life and the young girls are exposed to cultural and social messages and pressures concerning the body: adolescents perceive one's own body appearance as the most important part of the self and this may increase the tendency to evaluate their body as an object in the physical world (i.e. an allocentric representation of the body). It is possible that in the subjects with AN, the interaction between the allocentric reference frame memory of their body and the insufficient egocentric/somatosensorial updating may create a vicious cycle, also supported by the cultural social pressures on the body, which lock the AN subjects to an distorted allocentric representation of the body.

In conclusion, as for any new perspective, much more research is needed before it can be retained or discarded. In particular, new imaging studies are required to further explore the link between autobiographical memory and the experience of the body. Finally, clinical and longitudinal studies should compare in a controlled setting the effects of treatment strategies aimed at unlocking the body image of AN patients to test the real efficacy of this approach.

Competing financial interests

None.

Conflict of interest statement

None declared.

References

[1] Kaye WH, Fudge JL, Paulus M. New insights into symptoms and neurocircuit function of anorexia nervosa. Nat Rev Neurosci 2009;10:573–84.
[2] Naruo T, Nakabeppu Y, Sagiyama K, Munemoto T, Homan N, Deguchi D, et al. Characteristic regional cerebral blood flow patterns in anorexia nervosa patients with binge/purge behavior. Am J Psychiatry 2000;157:1520–2.
[3] Uher R, Murphy T, Brammer MJ, Dalgleish T, Phillips ML, Ng VW, et al. Medial prefrontal cortex activity associated with symptom provocation in eating disorders. Am J Psychiatry 2004;161:1238–46.
[4] Craig AD. How do you feel? Interoception: the sense of the physiological condition of the body. Nat Rev Neurosci 2002;3:655–66.
[5] Riva G. Neuroscience and eating disorders: the allocentric lock hypothesis. Med Hypotheses 2012;78:254–7.

Please cite this article in press as: Riva G, Gaudio S. Allocentric lock in anorexia nervosa: New evidences from neuroimaging studies. Med Hypotheses (2012), http://dx.doi.org/10.1016/j.mehy.2012.03.036

[6] Riva G. Neuroscience and eating disorders: the role of the medial temporal lobe. Nature Precedings (2010), <http://www.precedings.nature.com/documents/4235/>. [Accessed October 4236, 2010].
[7] Klatzky RL. Allocentric and egocentric spatial representations: definitions, distinctions and interconnections. In: Freska C, Habel C, Wender KF, editors. Spatial cognition: an interdisciplinary approach to representation and processing of spatial knowledge. Berlin: Springer-Verlag; 1998. p. 1–17.
[8] Frith U, de Vignemont F. Egocentrism, allocentrism, and Asperger syndrome. Conscious Cogn 2005;14:719–38.
[9] Zaehle T, Jordan K, Wustenberg T, Baudewig J, Dechent P, Mast FW. The neural basis of the egocentric and allocentric spatial frame of reference. Brain Res 2007;1137:92–103.
[10] Committeri G, Galati G, Paradis AL, Pizzamiglio L, Berthoz A, LeBihan D. Reference frames for spatial cognition: different brain areas are involved in viewer-, object-, and landmark-centered judgments about object location. J Cogn Neurosci 2004;16:1517–35.
[11] Amorim MA. "What is my avatar seeing?" The coordination of "out-of-body" and "embodied" perspectives for scene recognition across views. Visual Cognition 2005;10:157–99.
[12] Galati G, Lobel E, Vallar G, Berthoz A, Pizzamiglio L, Le Bihan D. The neural basis of egocentric and allocentric coding of space in humans: a functional magnetic resonance study. Exp Brain Res 2000;133:156–64.
[13] Parslow DM, Rose D, Brooks B, Fleminger S, Gray JA, Giampietro V, et al. Allocentric spatial memory activation of the hippocampal formation measured with fMRI. Neuropsychology 2004;18:450–61.
[14] Chan AW, Peelen MV, Downing PE. The effect of viewpoint on body representation in the extrastriate body area. Neuroreport 2004;15:2407–10.
[15] Saxe R, Jamal N, Powell L. My body or yours? The effect of visual perspective on cortical body representations. Cereb Cortex 2006;16:178–82.
[16] Vocks S, Busch M, Schulte D, Gronermeyer D, Herpertz S, Suchan B. Effects of body image therapy on the activation of the extrastriate body area in anorexia nervosa: an fMRI study. Psychiatry Res 2010;183:114–8.
[17] Hodzic A, Kaas A, Muckli L, Stirn A, Singer W. Distinct cortical networks for the detection and identification of human body. Neuroimage 2009;45:1264–71.
[18] Byrne P, Becker S, Burgess N. Remembering the past and imagining the future: a neural model of spatial memory and imagery. Psychol Rev 2007;114:340–75.
[19] Robinson JA, Swanson KL. Field and observer modes of remembering. Memory 1993;1:169–84.
[20] Cabeza R, Prince SE, Daselaar SM, Greenberg DL, Budde M, Dolcos F, et al. Brain activity during episodic retrieval of autobiographical and laboratory events: an fMRI study using a novel photo paradigm. J Cogn Neurosci 2004;16:1583–94.
[21] Cabeza R, St Jacques P. Functional neuroimaging of autobiographical memory. Trends Cogn Sci 2007;11:219–27.
[22] Svoboda E, McKinnon MC, Levine B. The functional neuroanatomy of autobiographical memory: a meta-analysis. Neuropsychologia 2006;44:2189–208.
[23] Spreng RN, Grady CL. Patterns of brain activity supporting autobiographical memory, prospection, and theory of mind, and their relationship to the default mode network. J Cogn Neurosci 2010;22:1112–23.
[24] Eich E, Nelson AL, Leghari MA, Handy TC. Neural systems mediating field and observer memories. Neuropsychologia 2009;47:2239–51.
[25] Clark DM, Wells A. A cognitive model of social phobia. In: Heimberg RG, Liebowitz MR, Hope DA, Schneier FR, editors. Social phobia: diagnosis, assessment, and treatment. New York: Guilford Press; 1995. p. 69–93.
[26] D'Argembeau A, Van der Linden M, d'Acremont M, Mayers I. Phenomenal characteristics of autobiographical memories for social and non-social events in social phobia. Memory 2006;14:637–47.
[27] Wells A, Papageorgiou C. The observer perspective: biased imagery in social phobia, agoraphobia, and blood/injury phobia. Behav Res Ther 1999;37:653–8.
[28] Osman S, Cooper M, Hackmann A, Veale D. Spontaneously occurring images and early memories in people with body dysmorphic disorder. Memory 2004;12:428–36.
[29] Blood SK. Body work: the social construction of women's body image. Hove, UK: Routledge; 2005.
[30] Fredrickson BL, Roberts TA, Noll SM, Quinn DM, Twenge JM. That swimsuit becomes you: sex differences in self-objectification, restrained eating, and math performance. J Pers Soc Psychol 1998;75:269–84.
[31] Grafton ST. Embodied cognition and the simulation of action to understand objects. Ann NY Acad Sci 2009;1156:97–117.
[32] Yang SJ, Gallo DA, Beilock SL. Embodied memory judgments: a case of motor fluency. J Exp Psychol Learn Mem Cogn 2009;35:1359–65.
[33] Barsalou LW, Niedenthal PM, Barbey AK, Ruppert JA. Social embodiment. In: Ross BH, editor. The psychology of learning and motivation, vol. 43. San Diego, CA: Academic Press; 2003. p. 43–92.
[34] Dijkstra K, Kaschak MP, Zwaan RA. Body posture facilitates retrieval of autobiographical memories. Cognition 2007;102:139–49.
[35] Riskind JH. Nonverbal expressions and the accessibility of life experience memories: a congruence hypothesis. Soc Cogn 1983;2:62–86.
[36] Byrne P, Becker S. A principle for learning egocentric-allocentric transformation. Neural Comput 2008;20:709–37.
[37] Vann SD, Aggleton JP, Maguire EA. What does the retrosplenial cortex do? Nat Rev Neurosci 2009;10:792–802.
[38] Gainotti G, Almonti S, Di Betta AM, Silveri MC. Retrograde amnesia in a patient with retrosplenial tumour. Neurocase 1998;4:519–26.
[39] Smeets MA, Ingleby JD, Hoek HW, Panhuysen GE. Body size perception in anorexia nervosa: a signal detection approach. J Psychosom Res 1999;46:465–77.
[40] Sachdev P, Mondraty N, Wen W, Gulliford K. Brains of anorexia nervosa patients process self-images differently from non-self-images: an fMRI study. Neuropsychologia 2008;46:2161–8.
[41] Riva G. The key to unlocking the virtual body: virtual reality in the treatment of obesity and eating disorders. J Diab Sci Technol 2011;5:283–92.
[42] Uher R, Murphy T, Friederich HC, Dalgleish T, Brammer MJ, Giampietro V, et al. Functional neuroanatomy of body shape perception in healthy and eating-disordered women. Biol Psychiatry 2005;58:990–7.
[43] Wagner A, Ruf M, Braus D, Schmidt MH. Neural activity changes and body image distortion in anorexia nervosa. Neuroreport 2003;14:2193–7.
[44] Castro-Fornieles J, Bargallo N, Lazaro L, Andres S, Falcon C, Plana MT, et al. A cross-sectional and follow-up voxel-based morphometric MRI study in adolescent anorexia nervosa. J Psychiatr Res 2009;43:331–40.
[45] Gaudio S, Nocchi F, Franchin T, Genovese E, Cannata V, Longo D, et al. Gray matter decrease distribution in the early stages of anorexia nervosa restrictive type in adolescents. Psychiatry Res 2011;191:24–30.
[46] Joos A, Kloppel S, Hartmann A, Glauche V, Tuscher O, Perlov E, et al. Voxel-based morphometry in eating disorders: correlation of psychopathology with grey matter volume. Psychiatry Res 2010;182:146–51.
[47] Mohr HM, Zimmermann J, Roder C, Lenz C, Overbeck G, Grabhorn R. Separating two components of body image in anorexia nervosa using fMRI. Psychol Med 2010;40:1519–29.
[48] Joos A, Hartmann A, Glauche V, Perlov E, Unterbrink T, Saum B, et al. Grey matter deficit in long-term recovered anorexia nervosa patients. Eur Eat Disord Rev 2011;19:59–63.
[49] Connan F, Murphy F, Connor SE, Rich P, Murphy T, Bara-Carill N, et al. Hippocampal volume and cognitive function in anorexia nervosa. Psychiatry Res: Neuroimaging 2006;146:117–25.
[50] Schwoebel J, Coslett HB. Evidence for multiple, distinct representations of the human body. J Cogn Neurosci 2005;17:543–53.
[51] Sirigu A, Grafman J, Bressler K, Sunderland T. Multiple representations contribute to body knowledge processing evidence from a case of autotopagnosia. Brain 1991;114(Pt 1B):629–42.
[52] Lou HC, Luber B, Crupain M, Keenan JP, Nowak M, Kjaer TW, et al. Parietal cortex and representation of the mental self. Proc Natl Acad Sci USA 2004;101:6827–32.
[53] Hodzic A, Muckli L, Singer W, Stirn A. Cortical responses to self and others. Hum Brain Mapp 2009;30:951–62.
[54] Williamson DA. Body image disturbance in eating disorders: a form of cognitive bias. Eat disord 1996;4:47–58.
[55] Altabe M, Thompson JK. Body image: a cognitive self-schema construct? Cogn Ther Res 1996;20:171–93.
[56] Johansson L, Ghaderi A, Hallgren M, Andersson G. Implicit memory bias for eating- and body appearance-related sentences in eating disorders: an application of Jacoby's white noise task. Cogn Behav Ther 2008;37:135–45.
[57] Rosen JC. Body image assessment and treatment in controlled studies of eating disorders. Int J Eat Disord 1996;19:341–3.
[58] Fairburn CG. Cognitive behavior therapy and eating disorders. New York: Guilford Press; 2008.
[59] Ferrer-Garcia M, Gutierrez-Maldonado J. The use of virtual reality in the study, assessment, and treatment of body image in eating disorders and nonclinical samples: a review of the literature. Body Image 2012;9:1–11.
[60] Burgess N, Becker S, King JA, O'Keefe JO. Memory for events and their spatial context: models and experiments. Philos Trans R Soc Lond 2001;356:1–11.

Please cite this article in press as: Riva G, Gaudio S. Allocentric lock in anorexia nervosa: New evidences from neuroimaging studies. Med Hypotheses (2012), http://dx.doi.org/10.1016/j.mehy.2012.03.036