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Allocentric lock in anorexia nervosa: New evidences from neuroimaging studies

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A B S T R A C T

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.

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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...
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 viewpoint [11,18,19], the observer 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 autobiographical 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 areas 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 autobiographical 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 themselves as if from an external point of view [26]. Research by Wells & Papa-georgiou [27] showed that, in recalling anxiety-provoking social situations, individuals with social phobia and agoraphobia are

fronto-parietal network including the superior occipital gyrus, the superior parietal lobe (precuneus), the anterior part of the calcarine sulci, the superior frontal gyrus, 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 Passlows et al. [13]. Galati et al. showed that allocentric coding activates a posterior parietal region, located in the parietal lobe 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 perspective 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.
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 autobiographical 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 [5,41].

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, Connn...
et al. [49] found a significant reduction in hippocampal volume (−8.2% right; −7.5% left) in AN patients and Giordano and colleagues (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 somatosensory 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/somatosensory 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 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/somatosensory updating may create a vicious cycle, also supported by the cultural social pressures on the body, which lock the AN subjects to a 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.

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