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SYMPOSIUM

The Key to Unlocking the Virtual Body: Virtual Reality in the Treatment of Obesity and Eating Disorders

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Abstract

Obesity and eating disorders are usually considered unrelated problems with different causes. However, various studies identify unhealthful weight-control behaviors (fasting, vomiting, or laxative abuse), induced by a negative experience of the body, as the common antecedents of both obesity and eating disorders. But how might negative body image—common to most adolescents, not only to medical patients—be behind the development of obesity and eating disorders?

In this paper, I review the "allocentric lock theory" of negative body image as the possible antecedent of both obesity and eating disorders.

Evidence from psychology and neuroscience indicates that our bodily experience involves the integration of different sensory inputs within two different reference frames: *egocentric* (first-person experience) and *allocentric* (third-person experience). Even though functional relations between these two frames are usually limited, they influence each other during the interaction between long- and short-term memory processes in spatial cognition. If this process is impaired either through exogenous (e.g., stress) or endogenous causes, the egocentric sensory inputs are unable to update the contents of the stored allocentric representation of the body. In other words, these patients are locked in an allocentric (observer view) negative image of their body, which their sensory inputs are no longer able to update even after a demanding diet and a significant weight loss. This article discusses the possible role of virtual reality in addressing this problem within an integrated treatment approach based on the allocentric lock theory.

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Introduction

Obesity and eating disorders are usually considered unrelated problems with different causes. However, research with adolescents is questioning this belief; apparently, unhealthful weight-control behaviors—such as fasting (going without eating for 24 hours for weight control), vomiting, or laxative abuse—are the common antecedents of both obesity and eating disorders.[1–6] For example, Neumark-Sztainer and colleagues[2] discussed the results of the Project EAT II (Eating Among Teens), a longitudinal study involving 2516 ethnically and socio-economically diverse adolescents. They report that, 5 years later, the use of unhealthful weight-control behaviors

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Abbreviations: (CBT) cognitive behavioral therapy, (VR) virtual reality

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increased six times the risk for binge eating with loss of control, three times the risk for being overweight, and two to five times the risk for extreme weight-control behaviors such as the use of diet pills and self-induced vomiting. A similar result was found by Stice and associates;[6] in a longitudinal studywhere fasting was the best predictor for the onset of binge eating and bulimia nervosa 5 years later.

Epidemiological studies indicate that childhood obesity has different ethnic, socioeconomic (compared with affluent white children, poor Hispanic, white, and black children have 2.7, 1.9, and 3.2 times higher odds of obesity, respectively), and behavioral risk factors.[7] Behavioral variables, such as higher television viewing and higher physical inactivity levels, were all independently associated with higher obesity prevalence.

In a 4-year longitudinal study on 496 adolescent girls, Stice and coworkers[5] studied the psychological and behavioral risk factors for the onset of obesity in adolescent girls. Their data show that participants who were on a weight-loss diet or who used maladaptive compensatory behaviors for weight control were at increased risk for obesity 4 years later.

The present results have several clinical implications. First, they suggest that it is particularly important to educate adolescents about effective weight-control strategies. This conclusion has been highlighted by Raynor and colleagues[8] who stated that, "randomized trials testing family-based, behavioral modification interventions for pediatric obesity, which provide low-calorie dietary prescriptions emphasizing nutrient-dense food choices, greatly improve weight status and show a decrease or no change in eating pathology in children." Second, the evidence that youths practicing unhealthful weight-control behaviors are at higher risk for obesity and eating disorders implies that prevention and treatment interventions should also focus on the causes of these behaviors.

In a message on the Yahoo Answers UK site, an adolescent girl writes, "I'm 16 - so the classic insecure girl - although on the outside I cover up with a massive personality and I seem really confident about myself but just recently and defiantly in the past few days I have been looking at myself and yes I can see bone but I also see fat - I know I'm skinny but I'm stupidly skinny yet I have a huge bum and boobs and I've stopped eating properly and it hurts." (*http://uk.answers.yahoo.com/question/index?qid=20100718191717AAvCXjN*).

The words of the girl clearly explain her behavior: she stopped eating properly because she did not like her body.[9] A study by Kostanski and Gullone[10] with a sample of 431 Australian preadolescent children (7 to 10 years) confirms this interpretation: preadolescents as young as 7 years of age are unsatisfied with their body appearance and deliberately engage in restrictive eating behaviors. But how does a negative body image influence the development of obesity and eating disorders? In their provocative editorial, Schwartz and Henderson admitted that there is no simple answer to this question.[11]

In this article, I review the "allocentric lock theory" proposed as an antecedent to both obesity and eating disorders.[12,13] Specifically, I consider the possibility of an allocentric negative body image that is not altered by contrasting egocentric representations driven by perception. In other words, these patients are locked to an allocentric (observer view) negative image of their body that their sensory inputs are unable to update even after dramatic body changes. I discuss the possible role of virtual reality (VR) in addressing this problem as part of an integrated treatment approach. Specifically, I recommend adding a 10-session body-image rescripting protocol based on VR to the treatments of obesity and eating disorders to improve long-term outcome. The results of two controlled trials with 211 obese patients[14] and 36 binge eating patients[15] are used to support this treatment recommendation.

Allocentric Lock Hypothesis

Our Experience of the Body

As noted by Klatzky,[16] "A reference frame is a means of representing the locations of entities in space." Evidence from psychology and neuroscience indicates that our spatial experience, including the bodily one, involves the integration of different sensory inputs within two different reference frames: *egocentric* and *allocentric* (see **Figure 1**).[17,18]

The egocentric frame (first-person view) refers to the body of the observer and allows him/her to locate objects relative to the body center (as in the video game *Crysis*; **Figure 1**, left-hand side); within this frame, the position of an object changes if the subject moves.[19] In contrast to this frame, the allocentric frame (third-person view) refers to space external to the perceiver. Within this frame, the position of an object does not change if the subject moves (as in the video game *Pac-Man*; **Figure 1**, right-hand side). More, the object thus exists even if there is no relation with the self or another person.[19]

These two frames have different sources of reference.[18] 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 the body.

The ability to represent and recall an object, including our own body, changes according to the frame of reference: 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.[19–21] For instance, imagine a subject who is trying to find the train station in an unknown city using a map. Using an egocentric perspective, the subject will rotate the map to align it with his actual physical heading. Using an allocentric perspective, the subject will mentally rotate himself to align his heading with the north/south orientation of the map.

These frames of reference also influence the way memories are stored and retrieved: using the egocentric frame, the remembering subject "sees" the event from his or her perspective as in normal perception (field mode; see **Figure 2**); using the allocentric frame, the remembering subject "sees" the self engaged in the event as an observer would (observer mode; see **Figure 2**).[21–23]

Developing an Allocentric Negative Body Image

As highlighted by many authors, the body has a critical role in the Western culture;[24–27] the body is not only the first and the most natural tool of man, but also a culturally negotiated symbol that shapes the self and the experience of the subject.

In this context, the body becomes a symbol of personal order or disorder:[28] slenderness is associated with happiness, success, and social acceptability; being overweight is linked to laziness, lack of willpower, and being out of control. In addition, to control our body, we are taught to disembody ourselves (self-objectification) and consider the body as an object that others look at.[29] In other words, our culture asks us to develop an allocentric view of ourselves by forcing us to view our body just as a series of measurements and value it more on the basis of appearance than performance.

This is also true for children and adolescents; they are aware of the actual size of their own bodies and are likely to have judged the acceptability of their own body. Many are dissatisfied, and some feel anxious despite having a healthy body size.[1,30] To reduce the impact of this situation, different governments and institutions are introducing laws or codes of conduct banning so-called "cult of the body" advertising—including fashion magazines, television, and Web sites—and making it illegal to publicly promote extreme thinness.

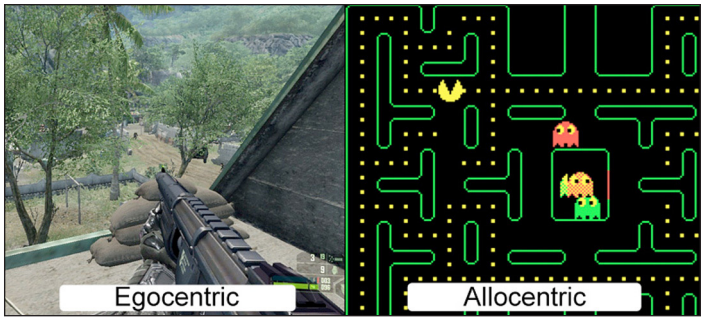

Figure 1. Egocentric and allocentric representation of space. The egocentric representation (on the left-hand side; image taken from the first-person shooter video game *Crysis*) integrates perceptual impressions gathered from a first-person perspective relative to the position and heading (front–back, right–left, and up–down) of the subject. In this representation, the world constantly changes while the navigator remains spatially fixed in the center of the reference system. The allocentric representation (on the right-hand side; image taken from the *Pac-Man* video game) instead establishes a "map" with an origin and a reference direction external to the subject. In this representation the world remains stationary while the subject moves inside it.

Figure 2. Field and observer modes in episodic memory. In field mode, the subject remembers the view of the Shenandoah Valley from his hiking experience through the subject's own eyes, as if he were looking outward (on the left-hand side). In the observer mode, the subject remembers the view of the Shenandoah Valley including him as an actor in the memory image (on the right-hand side).

Link with Anxiety Disorders

Anxiety disorders, which are common in patients with obesity and eating disorders, may also have a critical role in developing a negative allocentric body image. 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.[31]

Clark and Wells[32] propose that this self-processing occurs as an impression of appearance from an "observer perspective," seeing oneself as if from an external point of view (**Figure 2**).

As demonstrated by Eich and associates,[33] taking an observer perspective during autobiographical memory retrieval appears to significantly decrease activity in regions of the cerebral cortex associated with interoceptive awareness.

Episodic memory theories[34] also emphasize that the arousal associated with an object (e.g., a commercial using thin models) elicits focused attention (e.g., "my body in the mirror is not so thin as the one of the model") that enhances binding of its constituent features (e.g., "my body in the mirror is fat"), facilitating the development of an allocentric representation of the body (e.g., "I'm that disgusting body in the mirror"). The most important factor in this process seems to be how arousing the experiences are rather than their valence.[34]

Locked to an Allocentric Negative Body Image: How Neurosciences May Explain It

As suggested by Byrne and Becker,[35] the transformation from egocentric to allocentric representations of space is done by neurons in different medial temporal lobe structures. The hippocampus has a critical role in spatial memory by generating allocentric representations for long-term memory.[36] Furthermore, Parron and Save[37] suggested that the parietal cortex, the retrosplenial cortex, the entorhinal cortex, and the hippocampus are part of a functional network devoted to the processing of allocentric spatial information. Specifically, the lateral entorhinal cortex carries nonspatial information from the perirhinal cortex into the dorsal hippocampus, where it is combined with spatial information from the medial entorhinal cortex to create conjunctive object–place (or event–place) representations in the hippocampus.[38]

If this transformation is impaired, the subjects can no longer use the sensory inputs to update the contents of the allocentric representation of their body. This is what may be behind the etiology of obesity and eating disorders: a negative somatorepresentation—that is not updated by contrasting egocentric parietal representations driven by perception[39]—priming the processing of any further body-related experience.[40] In simpler words, the egocentric perception-driven experience of the real body is no longer able to modify the allocentric memory-driven experience of a negative body; these patients are locked in an allocentric (observer view) negative representation of their body.[13]

How does this happen? Apparently, psychological stress mechanisms—exogenous and/or endogenous—play a significant role in the functioning of the medial temporal lobe and may induce a locked negative body image. In fact, research underlines the role of anxiety and stress in influencing the brain areas involved in the egocentric/allocentric transformation. The endogenous cholinergic tone in the dorsal hippocampus decreases with increases in anxiety, and it is associated with an increase in the serotonergic tone.[41] Moreover, a growing body of evidence suggests that stress—and, in particular, chronic stress—can cause hippocampal damage[42,43] through the excessive activity exerted by the amygdala on the hippocampus.[44] Interestingly, this datum is in accordance with many studies suggesting the influence of interpersonal problems[45] and stress in the onset of eating disorders[46–49] and obesity.[50–52]

From an Allocentric Negative Body Image to Obesity and Eating Disorders

As stated earlier, in the Western culture, the body is considered a symbol of personal order or disorder: slenderness is associated with happiness, success, and social acceptability; being overweight is linked to laziness, lack of willpower, and being out of control.[28] Interestingly, our culture also provides a clear path for dealing with it: eating control. As reported by Rosen,[53] the most common reason for attempting to lose weight in women is the desire to improve physical appearance. This datum was confirmed by Lu and Hou:[54] in a sample of female college students, body dissatisfaction positively predicted their intention to lose weight ($\beta = .51$, $p < .001$)

From this perspective, the passage from a locked allocentric negative body image to obesity or eating disorders may be explained by social influence: media and culture promote diet and controlled eating as the best ways to improve body-image satisfaction. However, the impossibility of using sensory inputs for updating the allocentric representation of the body—patients hate their body even after a demanding diet and a significant weight loss—locks the patients in an unsatisfying body and into more and more radical attempts to improve it.

Use of Virtual Reality for Unlocking the Allocentric Negative Body Image

Virtual Reality in Behavioral Health Care

The convergence between technology and medicine[55,56] is providing new tools and methods for behavioral healthcare.[57] Between them, an emerging trend is the use of VR to improve the existing cognitive behavioral protocols for different psychological disorders, especially

anxiety disorders[58–63] and addiction.[64–67] Using VR, clinicians can offer in-office, systematic, controlled exposure therapy (VR exposure) to their patients, without the complications of *in vivo* exposure.[68] Moreover, the specific characteristics of the VR experience provide patients with a safe setting where they can exist and experience life,[69] thereby allowing them to be "emotionally present" inside the virtual environment.[70–72] Virtual reality can also be described as an advanced imaginal system: an experiential form of imagery that is as effective as reality in inducing emotional responses.[73–76]

Virtual Reality and the Experience of the Body

Virtual reality has also been used to induce controlled changes to the experience of the body.[77–79]

On one hand, different authors showed that is possible to use VR both to induce an illusory perception of a fake limb[80] or a fake hand[81] as part of our own body and to produce an out-of-body experience[79] by altering the normal association between touch and its visual correlate. It is even possible to generate a body transfer illusion: Slater and coworkers[80] substituted the experience of male subjects' own bodies with a life-sized virtual human female body.

On the other hand, it is also possible to use VR to improve body image,[82,83] even in patients with eating disorders[84,85] or obesity.[14,86] In a VR experiment, Burgess and colleagues[87] examined 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.

All these data suggest that it may be possible to use VR to induce a controlled sensory rearrangement that facilitates an update of the locked allocentric representation of the body.

A possible strategy toward this goal is the adaptation to VR the imagery rescripting method developed for the treatment of posttraumatic stress disorders.[88] Specifically, Riva[77,83] developed a specific body-image rescripting protocol based on VR (see **Table 1**) that was included as part of the experiential cognitive therapy.

Developed by Riva and associates,[89,90] experiential cognitive therapy is a relatively short-term (8–12 weeks), patient-oriented approach that focuses on individual discovery.[14,91] As in the case of cognitive behavioral therapy (CBT), experiential cognitive therapy uses a combination of nutritional, cognitive, and behavioral procedures to help the patient identify and change the maintaining mechanisms in both obesity and eating disorders (see **Table 2**). However, experiential cognitive therapy differs from the typical CBT approach in the VR body-image rescripting protocol, in its focus on empowerment, and in its focus on the negative emotions related to both body and eating.

In VR sessions, the therapist uses a "20/20/20 rule." During the first 20 minutes, the therapist focuses on getting a clear understanding of the patient's current concerns, level of general functioning, and experiences related to food. This part of the session tends to be characterized by patients doing most of the talking, although the therapist guides with questions and reflection to get a sense of the patient's current status. The second 20 minutes is devoted to the VR experience. During this part of the session, the patient enters the virtual environment and faces a specific critical situation (see **Table 1**). Here the patient is helped in developing specific strategies for avoiding and/or coping with it. In the final 20 minutes, the therapist explores the patient's understanding of what happened in VR and the specific reactions—emotional and behavioral—to the different situations experienced. If needed, some new strategies for coping with the VR situations are presented and discussed.

Experiential cognitive therapy has been tested in different case studies and two controlled trials with 211 obese patients[14] and 36 binge-eating patients.[15] Both controlled trials show that experiential cognitive therapy provides better results in the follow-up than competing approaches, including both nutritional therapy and CBT.

Possible consequences of interacting in a virtual environment are side effects such as nausea and dizziness.[92] However, in the studies aforementioned, thanks to the use of a commercial head-mounted display developed for use with video games (the Z800 Emagin 3D Visor), a VR exposure time no longer than 20 minutes, and the exclusion of subjects with vestibular problems (e.g., vertigo, labyrinthitis), no side effects were reported.

Conclusions

Other investigators have reported that a distorted body image that drives behavior and influences information processing may be associated with eating-related diseases.[93–95] Stice and Agras[96,97] introduced the "dual-pathway" model of bulimic pathology that has some

Table 1.
Virtual Reality Body-Image Rescripting Protocol

Phase 1: interview	During a clinical interview, the patient is asked to relive the contents of the allocentric negative body image and the situation(s) in which it was created and/or reinforced (e.g., being teased by my boyfriend at home) in as much detail as possible. The meaning of the experience for the patient was also elicited.
Phase 2: development of the VR scene	The clinician reproduces the setting of the identified situation (e.g., the corridor of the classroom where my boyfriend teased me) using one of the different scenes available in the free NeuroVR software (http://www.neurovr.org) The available scenes are as follows: • apartment • kitchen • office • school • restaurant • pub • supermarket • beach • swimming pool • city square • garden • the body-image room (in which the patient can select her/his ideal and perceived body from a list of predefined body shapes and compare them with her/his own real body)
Phase 3: allocentric experience of the VR scene	The patient is asked to re-experience the event in VR from a first-person perspective (the patient does not see his/her body in the scene), expressing and discussing his/her feelings.  The patient is then asked what needed to happen to change their feelings in a positive direction. The questions asked follow the Socratic approach, for example, ''What would need to happen for you to feel better? How does it look through the eyes of a third person? Is there anything you as a third person like to do? How do the other people respond?'' The main cognitive techniques used in this phase, if needed, are as follows: • *Countering*: Once a list of distorted perceptions and cognitions is developed, the process of countering these thoughts and beliefs begins. In countering, the patient is taught to recognize the error in thinking and substitute more appropriate perceptions and interpretations. • *Label shifting*: The patient first tries to identify the kinds of negative words she uses to interpret situations in her life, such as bad, terrible, obese, inferior, and hateful. The situations in which these labels are used are then listed. The patient and therapist replace each emotional label with two or more descriptive words.
Phase 4: egocentric experience of the VR scene	The patient is asked to re-experience the event in VR from a third-person perspective (the patient sees his/her body in the scene), intervening to both calm and reassure his/her virtual avatar and to counter any negative evaluation.  The main cognitive techniques used in this phase, if needed, are as follows: • *Alternative interpretation*: The patient learns to stop and consider other interpretations of a situation before proceeding to the decision-making stage. The patient develops a list of problem situations, evoked emotions, and interpretative beliefs. The therapist and patient discuss each interpretation and, if possible, identify the kind of objective data that would confirm one of them as correct. • *Deactivating the illness belief*: The therapist first helps the client list her beliefs concerning weight and eating. The extent to which the illness model influences each belief is identified. The therapist then teaches the client a cognitive/behavioral approach to interpreting maladaptive eating behaviors and shows they can be understood from this framework.

Table 2.
Structure of the Experiential Cognitive Therapy

Week 1	
Psychometric test (test)	
Psychodiagnostic interview	Preliminary group (motivation to treatment and definition of rehabilitative protocol)
Session 1 VR Assessment + body image (virtual balance + sitting room)	Nutritional assessment
Weeks 2 and 3	
Session 2 VR Eating control + interpersonal reframe (kitchen + bathroom + bedroom)	Nutritional group (2/3 sessions)
Session 3 VR Body image (body image VR scale)	Psychological group (1 session)
Session 4 VR Eating control (supermarket)	Physical activity
Weeks 4 and 5	
Session 5 VR Body image + interpersonal reframe (gymnasium)	Nutritional group (2/3 sessions)
Session 6 VR Eating control + interpersonal reframe (pub)	Psychological group (1 session)
Session 7 VR Body image + interpersonal reframe (clothes shop)	Physical activity
Weeks 6 and 7	
Session 8 VR Eating control + interpersonal reframe (restaurant)	Nutritional group (2/3 sessions)
Session 9 VR Body image + interpersonal reframe (swimming pool + beach)	Psychological group (1 session)
Session 10 VR Eating control + body image (kitchen + body image VR scale + 9 doors room)	Physical activity
Week 8	
	Psychological support (2/3 sessions)
	Physical activity
	Final group (motivation to out-patient phase)
Psychometric tests (retest)	

similarities with the proposed approach. In their view, internalization of the thin ideal contributes to body dissatisfaction because this ideal is virtually unattainable. This model hypothesizes that elevated pressure to be thin fosters body dissatisfaction because it promotes discontent with one's body. This increased body dissatisfaction, in turn, fosters dieting and negative affect, which consequently increases the risk for eating disorders.

However, our proposed theory has some advantage.

- It identifies the source of the distorted body image in a specific cognitive process, the egocentric–allocentric transformation in spatial cognition.
- This cognitive bias is not the only cause of the problem (necessary but not sufficient condition), but it is associated with two more factors:
  - The individual's inability to counter the bias using normal sensory inputs (allocentric lock).
  - The cultural suggestion promoted by media that the best way to address negative emotions related to the bias and to improve body image is through eating restraint and dietary control.

Virtual reality is a possible tool for modifying the locked negative body image. An integrated treatment—the experiential cognitive therapy—that included a specific body-image rescripting protocol based on VR was able to achieve good results in the long term with obese and binge-eating patients, and may be as good or better than other approaches involving nutritional and cognitive behavioral therapies.

Two final suggestions are made for improving programs used for weight control in adolescents. First, the inclusion of a body-image protocol, targeting body dissatisfaction, may reduce the rate of unhealthful weight-control behaviors. Second, the inclusion of a social support program, helping the adolescent to cope with interpersonal stress, may reduce the risk of an allocentric lock.

In conclusion, as for any new perspective, much more research is needed. However, treatment is best accomplished when we know the causes of a disorder. For this reason, any step, even if partial, toward a better understanding of obesity and eating disorders may be useful for advancing treatment of these complex and multifaceted diseases.

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