25 Virtual Reality for the Treatment of Body Image Disturbances in Eating and Weight Disorders

Giuseppe Riva, Santino Gaudio, Silvia Serino, Antonios Dakanalis, Marta Ferrer-García, and José Gutiérrez-Maldonado

25.1 Introduction

25.1.1 Virtual Reality: A Definition

What is Virtual Reality (VR)? If we follow the Oxford English Dictionary, the meaning of VR is: "A computer-generated simulation of a lifelike environment that can be interacted with in a seemingly real or physical way by a person, esp. by means of responsive hardware such as a visor with screen or gloves with sensors." (online: http://www.oed.com/view/Entry/328583?redirectedFrom=virtual+reality).

G. Riva (✉) · S. Serino
Centro Studi e Ricerche di Psicologia della Comunicazione, Università Cattolica del Sacro Cuore, Milan, Italy

Applied Technology for Neuro-Psychology Lab, Istituto Auxologico Italiano, Milan, Italy
e-mail: giuseppe.riva@unicatt.it

S. Gaudio
Department of Neuroscience, Functional Pharmacology, Uppsala University, Uppsala, Sweden

Centre for Integrated Research (CIR), Area of Diagnostic Imaging, Università "Campus Bio-Medico di Roma", Rome, Italy

A. Dakanalis
Department of Medicine and Surgery, University of Milano Bicocca, Milan, Italy

Department of Brain and Behavioral Sciences, University of Pavia, Pavia, Italy

Department of Clinical Psychology and Psychobiology, University of Barcelona, Barcelona, Spain

Applied Technology for Neuro-Psychology Lab, Istituto Auxologico Italiano, Milan, Italy

M. Ferrer-García · J. Gutiérrez-Maldonado
Department of Clinical Psychology and Psychobiology, University of Barcelona, Barcelona, Spain

M. Cuzzolaro, S. Fassino (eds.), *Body Image, Eating, and Weight*,
https://doi.org/10.1007/978-3-319-90817-5_25

In this definition VR is described as a set of fancy technologies [1–3]: an interactive *3D visualization system* (a computer, a game console, or a smartphone) supported by *input tools* (trackers, gloves, joystick, mice, etc.) that continually report the position and movements of the users; and ***output tools*** (visual, aural, haptic, etc.) that immerse the user in the virtual environment.

On the basis of the hardware and software included in a VR system, it is possible to distinguish between:

- **Desktop VR**: It uses as main output tool a standard PC screen. The feeling of immersion can be improved through stereoscopic vision. Input tools usually include a mouse, joystick, or typical VR peripherals such as a data glove.
- **Fully Immersive VR**: It uses advanced output devices (head-mounted display, force feedback robotic arms, etc.) and a system of head/body tracking to guarantee the exact correspondence and co-ordination of users' movements with the feedback of the environment. In immersive VR, the user appears to be fully inserted in the computer-generated environment.
- **CAVE**: This is a small room where a computer-generated world is projected on the walls. The projection is made on both front and side walls. This solution is particularly suitable for collective VR experiences because it allows different people to share the same experience at the same time.

NASA recently provided a less technical definition of VR: "the use of computer technology to create the effect of an interactive three-dimensional world in which the objects have a sense of spatial presence. In this definition, 'spatial presence' means that the objects in the environment effectively have a location in three-dimensional space relative to and independent of your position. Note that this is an effect, not an illusion. The basic idea is to present the correct cues to your perceptual and cognitive system so that your brain interprets those cues as objects" out there "in the three-dimensional world". (Online: https://www.nas.nasa.gov/Software/VWT/vr.html).

In this view, what distinguishes VR from other media is the sense of "presence," i.e., the feeling of "being there," in the synthetic experience produced by the technology [4, 5]. While there is still no general consensus about what presence actually *is* from a psychological viewpoint (for an introduction to the subject, see [6]), it is fair to say that most investigators agree about what it is *not* [7, 8]. As underlined by Riva and colleagues [9–25] "presence is not the degree of technological immersion, it is not the same thing as emotional engagement, it is not absorption or attention or action; but all of these have a potential role in understanding the experience of presence in interaction – the experience of interacting with presence" (p. 1).

25.1.2 The Clinical Use of VR

The sense of presence and emotional engagement offered by VR can be a powerful tool for personal change because it provides a high level of personal efficacy and self-reflectiveness [26]. As underlined by Glantz and colleagues [27]: "One reason it is so difficult to get people to update their assumptions is that change often requires a prior step – recognizing the distinction between an assumption and a perception. Until revealed to be fallacious, assumptions constitute the world; they seem like perceptions, and as long as they do, they are resistant to change" (p. 96). On one side, VR offers synthetic worlds in which an individual can be placed and live a particular experience [28]. More, VR allows a higher level of self-reflectiveness than that provided by memory and imagination, and a higher level of control than that offered by direct "real" experience [29]. In fact, VR has also been described as an experiential form of imagery that is as effective as reality in inducing emotional responses [30].

These features clearly explain the increasing use of VR in clinical psychology. In a recent publication, Riva et al. [29] reported the available reviews and meta-analyses about the use of VR in clinical and health psychology. They were related to addictions (2 reviews, 1 meta-analysis; 53 studies), pain (4 reviews; 48 studies), anxiety disorders (3 reviews, 4 meta-analyses; 175 studies), stress-related disorders (4 reviews; 41 studies), depression (1 review and meta-analysis; 19 studies), EDs (3 reviews; 33 studies), schizophrenia and other psychotic disorders (2 reviews, 1 meta-analysis; 23 studies), and autism (2 reviews; 39 studies). The highest number of studies has been conducted in anxiety disorders and stress-related disorders, supporting the efficacy of VR in the treatment of phobias, stress management, post-traumatic stress disorder, panic disorder, and agoraphobia. The evidence for the treatment of social phobia is not definitive. The reviews related to addictions show that VR is effective in inducing craving to substances such as cocaine, alcohol, and tobacco, allowing its use in cue exposure treatments and to develop coping skills. In autism, the reviews support the use of VR to train social skills. This kind of training has also been used in patients with schizophrenia, and preliminary results are promising, but there is still no strong evidence for the efficacy of VR in the treatment of this disorder and other psychotic disorders. Similarly, there is only evidence for a moderate effect of the VR interventions on depression. As a pain reduction technique, VR has shown strong efficacy in short-term interventions, but little evidence exists for longer-term benefits. In EDs, the reviews performed to date show that VR cue exposure to food stimuli and VR body image treatments are effective [31]. We will discuss more in detail these results in the next paragraphs.

25.1.3 Virtual Reality Technology

The implementation of VR-based applications for clinical use has always depended heavily on the development of advanced technology. Consequently, for a long time the research in this area was limited by the cost of the technology required. Furthermore, the field was largely restricted to academic research and very few technology companies sought to transfer the results of this research into clinical VR applications.

Today, however, VR technology is advancing quickly. Both Oculus Rift (http://www.oculus.com) and HTC (https://www.htcvive.com/) are showcasing high-quality VR experiences at reasonable price points—less than $2000 for a fully configured system—which are now widely available to consumers [32]. Thus, the first major obstacle to the widespread use of the VR seems to have been overcome. The second one, the presence of technological difficulties, remains, but probably not for very long. The use of VR systems involves the management of complex devices that require a certain level of technological knowledge and the assistance of technical staff. Therefore, it is not surprising that some therapists and clinicians, especially veteran practitioners, are reluctant to introduce VR systems into their daily practice. However, this scenario is about to change largely due to the expansion of VR in the field of consumer electronics; the commercialization of VR systems among the general population will bring down costs and enhance the development of user-friendly devices. Furthermore, for younger generations the use of VR technology will be part of their everyday routine and the technical difficulties will disappear.

25.2 Virtual Reality Applications in Eating and Weight Disorders

As discussed widely in other chapters of this book, body image disturbance is a central feature of eating and weight disorders (EWDs) and plays an important role in the development, maintenance, and risk of relapse of these conditions [6, 29, 33, 34]. However, the study of body disturbances is not easy. In fact, our experience of the body is not direct (Fig. 25.1), but it is [35–37]:

- Mediated by perceptual information.
- Influenced by internal information.
- Recalibrated through stored implicit and explicit body representation (body memory).

More, body image distortion can be seen as a multidimensional construct (Fig. 25.1) that, according to neuroimaging studies [38–45], includes three different components: cognitive, affective, and perceptive. The cognitive and affective components of body image distortion are widely accepted and related both:

- *To brain dysfunctions* [37, 40, 46]: alterations of the prefrontal cortex, the amygdala, and the insula [47], and
- *To sociocultural issues* [41, 46, 48]: internalization of an ideal body figure [43], social body comparison [49–51], and self-objectification [52].

Recent different functional magnetic resonance imaging (fMRI) [53] also suggest a perceptual component of body image distortion. According to Gaudio and colleagues “several brain regions could be involved body image disturbances and may sustain an impaired integration between real and perceived internal/external state of one’s own body in AN patients” (p. 582).

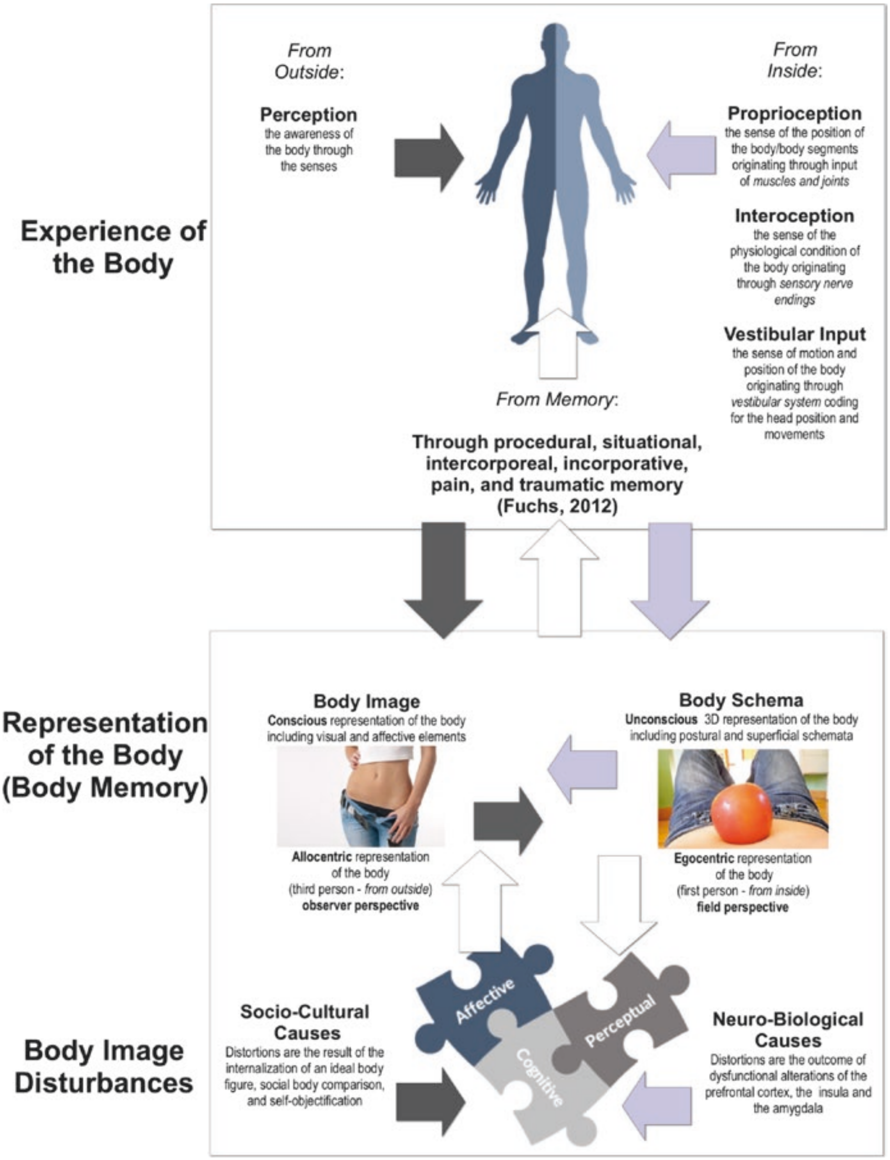

Fig. 25.1 From the experience of the body to body image disturbances

Given the complexity of body image, researchers usually target only one of the different components of body image disturbances [54–56]:

- *The perceptual distortion of body image*: the inability to perceive the size of the body accurately, and
- *The cognitive/affective body dissatisfaction*: the degree to which a person likes or dislikes the size and shape of his/her body and values it.

This complexity can also explain why body image disturbance is often overlooked in EWDs treatments, despite being considered a core feature of these disorders.

In this context, the development of VR has provided researchers and clinicians with a new technology that seems to be particularly well suited to the study, assessment, and treatment of body image disturbances for its ability of targeting all these dimensions. The use of immersive VR systems brings patients face to face with their virtual body in its actual size. More, VR simulates real-life situations in which different aspects of body image disturbances can be studied, assessed, and even treated in a secure, private, and controlled setting [57, 58]. Moreover, the possibility of developing three-dimensional figures that represent the body of the participants and whose size and shape can be modified enables patients to embody their mental representations of the different components of body image (e.g., perceived vs. ideal body image). Finally, VR allows bodily illusions [59–62]—the controlled illusory generation of unusual bodily feelings, such as the feeling of ownership over a virtual limb, that affect the experience of a body part or the entire body (i.e., body-swap illusion)—whose results have been presented in three recent reviews [63–65] and will be further discussed in the next paragraphs.

25.3 Virtual Reality for the Treatment of Body Image in EWDs: The Rationale

Most women are dissatisfied with their body [66]: one adolescent girl out of two reports body dissatisfaction [42]. For this reason, the "objectification theory" suggests a significant role of culture and society in the etiology of these disorders. Introduced by Fredrickson and Roberts [67], this theory suggests that our culture imposes a specific self-evaluation model—self-objectification—that defines women's behavioral and emotional responses [68].

At its simplest, the objectification theory holds that [69]:

1. There exists an objectified societal ideal of beauty (within a particular culture).
2. This is transmitted via a variety of sociocultural channels.
3. This ideal is then internalized by individuals.
4. Satisfaction (or dissatisfaction) with appearance will be a function of the extent to which individuals do (or do not) meet the ideal prescription.

According to Fredrickson and colleagues [70, 71], repeated experiences of sexual objectification—when women are treated as bodies that exist for the use and pleasure of others—cause them to gradually adopt an observer's perspective of their physical self; that is, they begin to treat themselves as an object to be looked at and evaluated on the basis of physical appearance. The self is so defined in terms of how the body appears to others.

The internalization of an observer's perspective on one's own body is labeled as "self-objectification" [72] and reduces a woman's worth to her perception of her body's semblance to cultural standards of attractiveness [69]. Self-objectification is typically manifested as persistent body surveillance or habitual monitoring of the body's outward appearance and is believed to lead to different negative experiential consequences such as body shame, social physique anxiety, lack of awareness of internal bodily states, and decreased peak motivational states/flow experiences [73, 74], and is recognized as the most robust risk factor for clinical and subclinical EWDs [43, 75].

There are two possible criticisms of this view. The first is that males, who apparently are less prone to self-objectification, also experience EWDs. Second, only a small subset of all the female and male subjects exposed to idealized body models develop clinically diagnosable EWDs [76].

Nevertheless, different recent studies have underlined the possible role of self-objectification in the etiology of male EWDs [43, 71, 76–78]. Specifically in males, self-objectification is manifested as body surveillance [79].

A possible response to the second criticism is offered by a new etiological model, i.e., the "*Allocentric Lock (AL) Theory*" [20, 52, 80–82]. This theory suggests that EWDs, including anorexia nervosa, are the outcome of a deficit in the processing and integration of multisensory bodily representations and signals [40, 83, 84] that alters the way the body is "experienced" and "remembered." Specifically, individuals with (or developing) this disorder may be locked to an allocentric (third person) disturbed memory of their body that, independently of its causes, is not more updated by experiential data, even after a successful diet and/or a significant weight reduction (Fig. 25.2).

Differently from other physical objects, our body is experienced both as object (third person)—we perceive our body as a physical object in the external world—and as subject (first person)—we experience our body through different neural representations that are not related to its physical appearance [85].

These frames influence also the way memories are stored and retrieved [86, 87]: 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). More, they influence the ability of representing and recalling our body: an egocentric representation of how our body looks is matched by an allocentric one, used by our brain in different situations [88]: from spatial cognition to social perception.

But what are the differences between field and observer modes of remembering? As Eich and colleagues clearly underline [87]: "…adopting an observer perspective is tantamount to a literal disembodiment at the neural level." (p. 177). In simpler words, remembering our body in the observer mode overrides the actual contents of our bodily self-consciousness. If this process is impaired for either exogenous (i.e., high level of stress) or endogenous causes (i.e., alteration of neurotransmitters and/or brain areas), the experience of the body is locked to an old memory.

From a cognitive viewpoint, this situation can be explained as the effect of a functional disconnection between top-down, premorbidly learned predictions regarding the experience of the body and the processing of bottom-up perceptual information regarding its current state [20, 74].

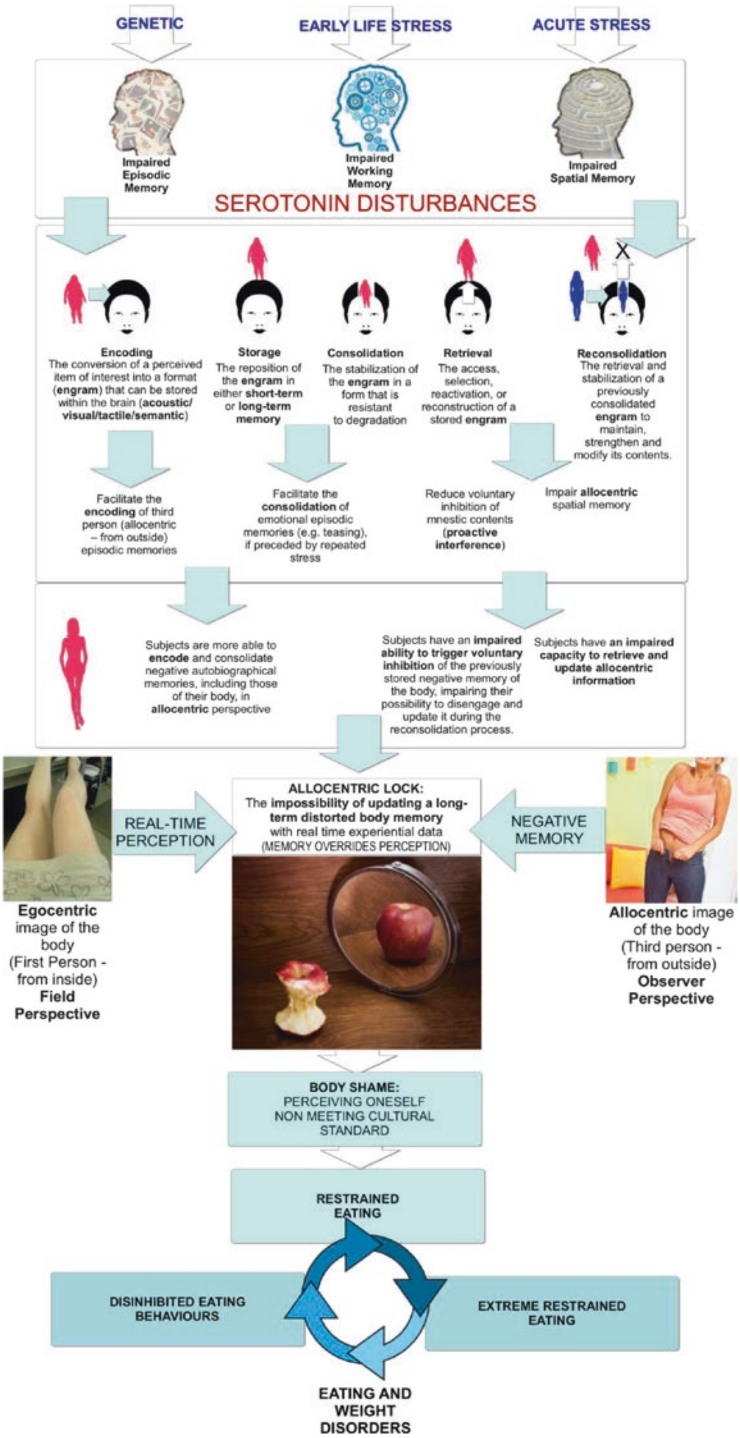

Fig. 25.2 The allocentric lock theory

More, this theory also fits well with the recent neurobiological model developed by Kaye and colleagues [89, 90] suggesting that AN patients are characterized by a dysregulation in the anterior ventral striatal pathway that may create a vulnerability for dysregulated appetitive behaviors. One of the effects of this dysregulation is an altered serotoninergic activity [91–94] related to the impairment of serotonin (5-HT) neurotransmitters. As discussed in a recent review [40], serotonin disturbances may (see Fig. 25.2):

- Facilitate the encoding of allocentric (from outside) episodic memories.
- Facilitate the consolidation of emotional episodic memories (e.g., teasing), if preceded by repeated stress.
- Reduce voluntary inhibition of mnestic contents.
- Impair allocentric spatial memory.

If we discuss these data within the interpretative frame suggested by the allocentric lock hypothesis, it is possible to hypothesize that these patients [40]:

(a) *Are more able to store and consolidate negative autobiographical memories, including those of their body, in allocentric perspective*.
(b) *Have an impaired ability to trigger voluntary inhibition of the previously stored negative memory of the body, impairing their possibility to disengage and update it during the reconsolidation process*.
(c) *Have an impaired capacity to retrieve and update allocentric information*.

In conclusion, there is a possible link between serotonin dysfunctions and body image disturbances in AN: the impossibility of updating a disturbed body memory using real-time experiential data—I'm locked to an old negative body stored in long-term memory—pushes patients to control body weight and shape even when underweight. Moreover, if even successful dieting attempts are unable to balance body image disturbance, people may either start more radical dieting attempts or, at the opposite end, all their attempts to control eating are abandoned and they engage in disinhibited eating behaviors that can be followed by compensatory behaviors, which can turn into a vicious cycle (for a broader review, see [95, 96]).

25.4 Virtual Reality for the Treatment of Body Image in EWDs: Protocols and Studies

To modify this situation, the use of VR, a synthetic egocentric experience, is an emerging and promising approach [97–100]. In particular, the two research groups mentioned above (Riva's group in Milan and Perpiñá's group in Castellón and Valencia) are using VR to improve CBT, and have also developed VR-based software for the assessment and treatment of body image disturbances [101].

The first approach is offered by VR-enhanced cognitive behavior therapy called Experiential Cognitive Therapy (ECT) developed by Giuseppe Riva and his group inside the VREPAR and VEPSY Updated European funded projects. It is a relatively short-term, patient-oriented approach that focuses on individual discovery [102]. ECT shares with CBT the use of a combination of cognitive and behavioral procedures to help the patient identify and change the maintaining mechanisms. However, it differs from CBT in the following ways:

- *Use of VR*: There are 15 VR sessions. The first session is used to assess any stimuli that could elicit abnormal eating behavior. Specifically, attention is focused on the patient's concerns about food, eating, shape, and weight. At the end of the first VR session the therapist uses the *miracle question*, a typical approach used by the solution-focused brief therapy [103–106]. Using VR to experience the effects of the miracle [34, 107–110] individuals are more likely not only to gain an awareness of their need to do something to create change but also to experience a greater sense of personal efficacy.
- *Focus on the negative emotions related to the body (a major reason patients want to lose weight) and on supporting the empowerment process*. In eight VR sessions, the therapist helps patients to recognize why they eat and what they need to either avoid or cope with specific emotional/behavioral triggers. Cue exposure techniques are also used [111, 112]. During exposure, patients face high-risk situations for reducing or extinguishing the conditioned response of anxiety when exposed to food-related cues [113, 114]. Exposure ends after a significant reduction in the level of anxiety.
- *Focus of the experience of the body:* VR is used in a sensory training to unlock the body memory (body image rescripting protocol) by increasing the contribution of new egocentric/internal somatosensory information directly related to the existing allocentric memory [31, 115]. In the protocol (see Fig. 25.3), involving six VR sessions, different body-related situations are experienced from both first-person (the patient does not see his/her body in the scene) and third-person perspectives (the patient sees his/her body in the scene) integrating the therapeutic methods used by Butter and Cash [116] and Wooley and Wooley [117].

This approach was validated by various case studies [3, 118] and trials [107, 119–122].

The most recent controlled trial (ISRCTN59019572) included 211 obese (BMI>40 female patients and 90 obese (BMI>40) female patients with BED [109, 110]. In the trial ECT was compared with CBT and an integrated treatment (IT) including nutritional groups, a low-calorie diet (1200 kcal/day) and physical training.

In both studies [109, 110], only ECT was effective at improving weight loss at 1-year follow-up. Conversely, control participants regained most of the weight they had lost during the inpatient program.

Furthermore, in the BED study [109] binge eating episodes decreased to zero during the inpatient program but were reported again in all the groups at 1-year follow-up. However, a substantial regain was observed only in the group who received the integrated treatment alone, while both ECT and CBT were successful in maintaining a low rate of monthly binge eating episodes.

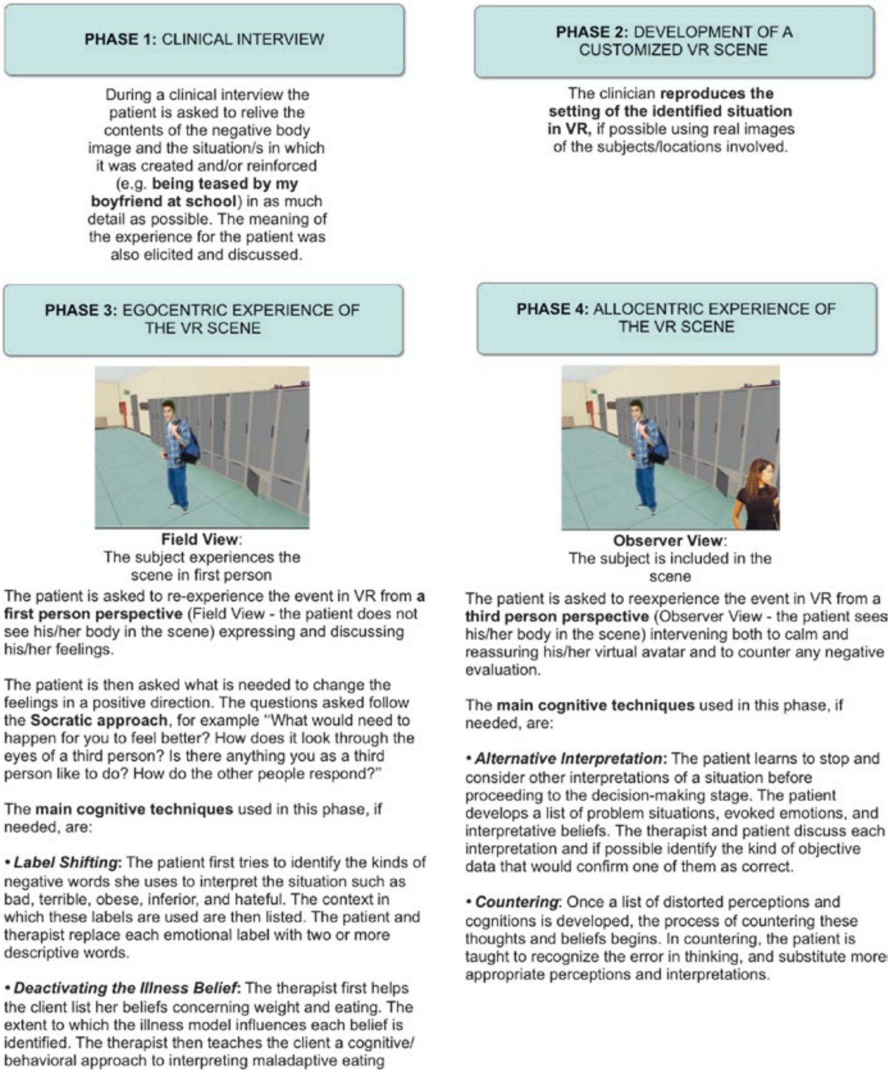

Fig. 25.3 The VR body image rescripting protocol (Adapted from Riva et al. 2006, Riva, 2011)

To further improve the efficacy of ECT, Riva and colleagues recently started to explore the possibility of integrating the emerging field of bodily illusions in the protocol [115, 123]. A first study [97] showed that the body-swap illusion was able to update the negative stored representation of the body. It has been found that after embodying a virtual body with a skinny belly, women updated their "remembered body," reporting a significant (post-illusion) decrease in their body-size distortion. A similar result was obtained recently by Keizer and colleagues [124] using body swapping with a sample of 30 anorectic subjects: they decreased the overestimation of their shoulders, abdomen, and hips both after the illusion was induced and after a short follow-up (2 h and 45 min after the illusions).

Support for the use of bodily illusions to alter the dysfunctional experience of the bodily self also came from a recent published study [125] showing that a (VR) body-swap illusion, which generates the (converse) illusion that a fat person is thin, was able to increase body satisfaction and reduce body-size distortion in a non-operable super-super obese patient (i.e., with body mass index >60 kg/m^2). In addition to the improvement in the bodily experience, the illusion was able to increase the patient's motivation to maintain healthy eating behaviors. While no studies to date have directly exploited the potential of bodily illusions in ED treatment, the evidence deriving from the extant experimental studies may suggest clinical applications for these methods [65, 126, 127].

Preston and Ehrsson [128] also used these illusions to explore the relation between body satisfaction and body perception. The body swapping was induced over a mannequin body digitally manipulated to be both wider and slimmer than the participants' actual body size. The results showed that the illusion of ownership over a slimmer body significantly decreases perceived body width and increases body satisfaction. Preston and colleagues [129] also used multisensory full-body illusions to modulate feelings of ownership over a mannequin body. The third-person mirror perspective elicited strong feelings of ownership over the mannequin and increased physiological responses to the mannequin being threatened. This result suggests that mirrors are special for viewing the self by providing a unique first-person perspective of our body from the outside. In a later study, Preston and Ehrsson [130] used multisensory illusions to elicit illusory ownership of obese and slim bodies during functional magnetic resonance imaging. Their results suggest the involvement of the anterior insula and the anterior cingulate cortex in the development of negative feelings toward the body through functional interactions with the posterior parietal cortex, which mediates perceived obesity.

Perpiñá's group compared the effectiveness of VR with that of CBT for body image improvement. Specifically, they developed six different virtual environments, including a 3D figure whose body parts (arms, thighs, legs, breasts, stomach, buttocks, etc.) could be enlarged or reduced. The proposed approach addressed several body image dimensions: the body could be evaluated wholly or in parts; the body could be placed in different contexts (for instance, in the kitchen, before eating, after eating, facing attractive persons, etc.); behavioral tests could be performed in these contexts, and several discrepancy indices related to weight and figure could be combined (actual weight, subjective weight, desired weight, healthy weight, how the person thinks others see her/him, etc.).

In the published trial, 18 outpatients who had been diagnosed as suffering from EDs disorders (AN or BN) were randomly assigned to one of the two treatment conditions: the VR condition (CBT plus VR) and the standard body image treatment condition (CBT plus relaxation). The results showed that all patients improved significantly following treatment. However, those who had been treated with the VR component showed a significantly greater improvement in general psychopathology, ED psychopathology, and specific body image variables. What is more, these results were maintained at 1-year follow-up [131].

This group's most recent controlled trial included 34 patients diagnosed with ED [42]. Seventeen patients underwent VR-enhanced CBT and 17 classical CBT. The CBT program for EDs enhanced by a body image-specific component using VR techniques was shown to be more efficient than CBT alone. Furthermore, improvement was maintained in post-treatment and at 1-year follow-up.

Conclusions

VR has proven to be a useful technology in the study, assessment, and treatment of a variety of psychological disorders. Studies on the application of this technology in the treatment of EDs were some of the first ones conducted in the early 1990s. Since then, several VR applications have been developed to be used in conjunction with traditional treatments, and their effectiveness has been tested in case studies, as well as in non-controlled and controlled trials. VR-based interventions in EDs usually combine exposure to VR environments with components based on CBT.

Although various longitudinal studies highlight the unhealthy weight-control behaviors used to counter body dissatisfaction as the common antecedents of eating and weight disorders, trans-disciplinary efforts for further elucidating this mechanism and improving the effectiveness of the available evidence-based interventions are imperative at this time.

To achieve a better explanation of these mechanisms, Riva proposed the "Allocentric Lock Hypothesis" [20, 43, 52, 74, 82, 83]. The key hypothesis of this framework is that both OB and EDs [i.e., Anorexia Nervosa (AN) and Bulimia Nervosa (BN)] are the outcome of a deficit in the processing and integration of multisensory bodily representations and signals [40, 83, 84] that alters the way the body is "experienced" and "remembered": EWDs patients may be locked to an allocentric disembodied negative memory of the body that is not updated even after a demanding diet and a significant weight loss. They cannot win: whatever they will do to modify their real body, they will be always present in a virtual body that they hate (e.g., "My body is fat").

As presented and discussed in this chapter, virtual reality can have a key role in the process of updating and improving the experience of the body [5]. So, it is likely that some of the new interventions on EWDs that derive from the allocentric lock theory and from the findings related to multisensory bodily illusions may be enhanced by the use of virtual reality, as recently demonstrated by different pioneering studies [65, 124, 125].

In conclusion, the two factors that are currently holding back the widespread use of VR technology in this field are the high cost and complexity of its use and maintenance [28]. The first of these barriers is about to disappear. As noted above, high-quality, highly immersive HMD devices are now available at a remarkably low cost [32]. Support should now be provided for the testing of new devices as they become available in order to assess the value of VR in clinical and health psychology as a whole, and more specifically in the field of EWDs.

Acknowledgments This chapter was supported by the research project: "Unlocking the memory of the body: Virtual Reality in Anorexia Nervosa" (201597WTTM) by the Italian Ministry of Education, Universities and Research.

References

1. Riva G, editor. Virtual reality in neuro-psycho-physiology: cognitive, clinical and methodological issues in assessment and rehabilitation. Amsterdam: IOS Press; 1997.
2. Riva G, Melis L, Bolzoni M. Treating body image disturbances. Commun ACM. 1997;40(8):69–71.
3. Riva G. Modifications of body image induced by virtual reality. Percept Mot Skills. 1998;86:163–70.
4. Wiederhold BK, Riva G, Gutiérrez-Maldonado J. Virtual reality in the assessment and treatment of weight-related disorders. Cyberpsychol Behav Soc Netw. 2016;19(2):67–73.
5. Gutierrez-Maldonado J, Wiederhold BK, Riva G. Future directions: how virtual reality can further improve the assessment and treatment of eating disorders and obesity. Cyberpsychol Behav Soc Netw. 2016;19(2):148–53.
6. Riva G, et al. Presence-inducing media for mental health applications. In: Lombard M, et al., editors. Immersed in media. New York: Springer; 2015. p. 283–332.
7. Riva G, Waterworth JA. Presence and the self: a cognitive neuroscience approach. Presence-Connect. 2003;3(1). http://presence.cs.ucl.ac.uk/presenceconnect/articles/Apr2003/jwworthApr72003114532/jwworthApr72003114532.html.
8. Gorini A, et al. The role of immersion and narrative in mediated presence: the virtual hospital experience. Cyberpsychol Behav Soc Netw. 2011;14(3):99–105.
9. Zahoric P, Jenison RL. Presence as being-in-the-world. Presence Teleoperators Virtual Environ. 1998;7(1):78–89.
10. Riva G, Waterworth JA, Murray D, editors. Interacting with presence: HCI and the sense of presence in computer-mediated environments. Berlin: De Gruyter Open; 2014. http://www.presence-research.com/.
11. Riva G, Davide F, IJsselsteijn WA, editors. Being there: concepts, effects and measurements of user presence in synthetic environments. In: Riva G, Davide F, editors. Emerging communication: studies on new technologies and practices in communication. Amsterdam: Ios Press; 2003. http://www.emergingcommunication.com/volume5.html.
12. Lee KM. Presence, explicated. Commun Theory. 2004;14(1):27–50.
13. Lombard M, et al., editors. Immersed in media. Telepresence theory, measurement & technology. Heidelberg: Springer; 2015.
14. Waterworth JA, Riva G. Feeling present in the physical world and in computer-mediated environments. Basingstoke: Palgrave Macmillan; 2014.
15. Banos RM, et al. Immersion and emotion: their impact on the sense of presence. Cyberpsychol Behav. 2004;7(6):734–41.
16. Banos RM, et al. Presence and emotions in virtual environments: the influence of stereoscopy. Cyberpsychol Behav. 2008;11(1):1–8.
17. Pillai JS, Schmidt C, Richir S. Achieving presence through evoked reality. Front Psychol. 2013;4:86.
18. Di Lernia D, Serino S, Pezzulo G, Pedroli E, Cipresso P, Riva G. Feel the time. Time perception as a function of interoceptive processing. Front Hum Neurosci. 2018;12:74. https://doi.org/10.3389/fnhum.2018.00074.
19. Seth AK, Suzuki K, Critchley HD. An interoceptive predictive coding model of conscious presence. Front Psychol. 2011;2:395.
20. Riva G. Neuroscience and eating disorders: the allocentric lock hypothesis. Med Hypotheses. 2012;78:254–7.
21. Riva G. Is presence a technology issue? Some insights from cognitive sciences. Virtual Real. 2009;13(3):59–69.

22. Ling Y, et al. A meta-analysis on the relationship between self-reported presence and anxiety in virtual reality exposure therapy for anxiety disorders. PLoS One. 2014;9(5):e96144.
23. Sanchez-Vives MV, Slater M. From presence to consciousness through virtual reality. Nat Rev Neurosci. 2005;6(4):332–9.
24. Slater M, Wilbur S. A framework for immersive virtual environments (FIVE): Speculations on the role of presence in virtual environments. Presence Teleoperators Virtual Environ. 1997;6(6):603–16.
25. Slater M. Presence and the sixth sense. Presence Teleoperators Virtual Environ. 2002;11(4):435–9.
26. Riva G, Gaggioli A, Villani D, Preziosa A, Morganti F, Corsi R, et al. NeuroVR: an open source virtual reality platform for clinical psychology and behavioral neurosciences. Stud Health Technol Inform. 2007;125:394–9.
27. Glantz K, et al. Virtual reality (VR) and psychotherapy: opportunities and challenges. Presence Teleoperators Virtual Environ. 1997;6(1):87–105.
28. Riva G, Gamberini L. Virtual reality in telemedicine. Telemed J E Health. 2004;6(3):327–40. https://doi.org/10.1089/153056200750040183.
29. Riva G, Baños RM, Botella C, Mantovani F, Gaggioli A. Transforming experience: the potential of augmented reality and virtual reality for enhancing personal and clinical change. Front Psych. 2016;7:164.
30. Vincelli F. From imagination to virtual reality: the future of clinical psychology. Cyberpsychol Behav. 1999;2(3):241–8.
31. Riva G. Letter to the Editor: virtual reality in the treatment of eating and weight disorders. Psychol Med. 2017;47(14):2567–8.
32. Zanier ER, Zoerle T, Di Lernia D, Riva G. Virtual reality for traumatic brain injury. Front Neurol. 2018;9:345.
33. Dakanalis A, Timko A, Serino S, Riva G, Clerici M, Carrà G. Prospective psychosocial predictors of onset and cessation of eating pathology amongst college women. Eur Eat Disord Rev. 2016;24(3):251–6.
34. Dakanalis A, Gaudio S, Serino S, Clerici M, Carrà G, Riva G. Body-image distortion in anorexia nervosa. Nat Rev Dis Primers. 2016;2:16026.
35. Riva G. The neuroscience of body memory: From the self through the space to the others. Cortex. 2018;104:241–60.
36. Blanke O, Slater M, Serino A. Behavioral, neural, and computational principles of bodily self-consciousness. Neuron. 2015;88(1):145–66.
37. Pazzaglia M, Zantedeschi M. Plasticity and awareness of bodily distortion. Neural Plast. 2016;2016:9834340.
38. Cash TF, Deagle EA. The nature and extent of body-image disturbances in anorexia nervosa and bulimia nervosa: a meta-analysis. Int J Eat Disord. 1997;22(2):107–26.
39. Gaudio S, Nocchi F, Franchin T, Genovese E, Cannatà V, Longo D, Fariello G. Gray matter decrease distribution in the early stages of Anorexia Nervosa restrictive type in adolescents. Psychiatry Res. 2011;191(1):24–30.
40. Riva G. Neurobiology of anorexia nervosa: serotonin dysfunctions link self-starvation with body image disturbances through an impaired body memory. Front Hum Neurosci. 2016;10:600.
41. Esposito R, et al. The role of body image and self-perception in anorexia nervosa: the neuroimaging perspective. J Neuropsychol. 2018;12(1):41–52.
42. Marco JH, Perpiñá C, Botella C. The treatment of the body image disturbances in eating disorders and clinically significant change. Ann Psychol. 2014;30(2):422–30.
43. Dakanalis A, Riva G. Mass media, body image and eating disturbances: the underline mechanism through the lens of the objectification theory. In: Latzer J, Merrick J, Stein D, editors. Body image: gender differences, sociocultural influences and health implication. New York: Nova Science; 2013. p. 217–36.
44. Eshkevari E, et al. Persistent body image disturbance following recovery from eating disorders. Int J Eat Disord. 2014;47(4):400–9.
45. Thompson JK, Smolak L. Body image, eating disorders, and obesity in youth: assessment, prevention, and treatment. New York: Taylor & Francis; 2001.

46. Sato Y, et al. Neural basis of impaired cognitive flexibility in patients with anorexia nervosa. PLoS One. 2013;8(5):e61108.
47. Gaudio S, Quattrocchi CC. Neural basis of a multidimensional model of body image distortion in anorexia nervosa. Neurosci Biobehav Rev. 2012;36(8):1839–47.
48. Suchan B, Vocks S, Waldorf M. Alterations in activity, volume, and connectivity of body-processing brain areas in anorexia nervosa. Eur Psychol. 2015;20(1):27–33.
49. van den Berg P, et al. The Tripartite Influence model of body image and eating disturbance: a covariance structure modeling investigation testing the mediational role of appearance comparison. J Psychosom Res. 2002;53(5):1007–20.
50. Tylka TL. Refinement of the tripartite influence model for men: dual body image pathways to body change behaviors. Body Image. 2011;8(3):199–207.
51. Swami V. Cultural influences on body size ideals unpacking the impact of westernization and modernization. Eur Psychol. 2015;20(1):44–51.
52. Riva G, Gaudio S, Dakanalis A. The neuropsychology of self-objectification. Eur Psychologist. 2015;20(1):34–43.
53. Gaudio S, Wiemerslage L, Brooks SJ, Schiöth HB. A systematic review of resting-state functional-MRI studies in anorexia nervosa: evidence for functional connectivity impairment in cognitive control and visuospatial and body-signal integration. Neurosci Biobehav Rev. 2016;71:578–89.
54. Cash TF. Body image: past, present, and future. Body Image. 2004;1(1):1–5.
55. Grogan S. Body image: understanding body dissatisfaction in men, women and children. 3rd ed. New York: Routledge; 2016.
56. Halliwell E. Future directions for positive body image research. Body Image. 2015;14:177–89.
57. Gutierrez-Maldonado J, Ferrer-Garcia M, Dakanalis A, Riva G. Virtual reality: applications to eating disorders. In: Agras SW, Robinson A, editors. The Oxford handbook of eating disorders. 2nd ed. Oxford: Oxford University Press; 2017. p. 146–61.
58. Riva G, Gutiérrez-Maldonado J, Wiederhold BK. Virtual worlds versus real body: virtual reality meets eating and weight disorders. Cyberpsychol Behav Soc Netw. 2016;19(2):63–6.
59. Serino S, Dakanalis A. Bodily illusions and weight-related disorders: clinical insights from experimental research. Ann Phys Rehabil Med. 2017;60(3):217–9.
60. Olive I, Berthoz A. Combined induction of rubber-hand illusion and out-of-body experiences. Front Psychol. 2012;3:128.
61. Pomes A, Slater M. Drift and ownership toward a distant virtual body. Front Hum Neurosci. 2013;7:908.
62. Maselli A, Slater M. Sliding perspectives: dissociating ownership from self-location during full body illusions in virtual reality. Front Hum Neurosci. 2014;8:693.
63. Costantini M. Body perception, awareness, and illusions. Wiley Interdiscip Rev Cogn Sci. 2014;5(5):551–60.
64. Gallace A, Spence C. Outside the boundaries of our bodies: the relationship between touch and the representation of the body in our mind. In: Gallace A, Spence C, editors. In touch with the future: the sense of touch from cognitive neuroscience to virtual reality. Oxford: Oxford University Press; 2014. p. 102–24.
65. Serino S, Scarpina F, Dakanalis A, Keizer A, Pedroli E, Castelnuovo G, et al. The role of age on multisensory bodily experience: an experimental study with a virtual reality full-body illusion. Cyberpsychol Behav Soc Netw. 2018;21(5):304–10. https://doi.org/10.1089/cyber.2017.0674.
66. Riva G. Virtual environment for body-image modification: virtual reality system for the treatment of body image disturbances. Comput Hum Behav. 1998;14(3):477–90.
67. Fredrickson BL, Roberts T. Objectification theory: toward understanding women's lived experiences and mental health risks. Psychol Women Q. 1997;21:173–206.
68. Calogero RM, Tantleff-Dunn S, Thompson JK. Self-objectification in women: causes, consequences, and counteractions. Washington, DC: American Psychological Association; 2010.
69. Dakanalis A, Carra G, Calogero R, Fida R, Clerici M, Zanetti MA, Riva G. The developmental effects of media-ideal internalization and self-objectification processes on adolescents'

negative body-feelings, dietary restraint, and binge eating. Eur Child Adolesc Psychiatry. 2015;28(8):997–1010. https://doi.org/10.1007/s00787-014-0649-1.
70. Fredrickson BL, Roberts TA, Noll SM, Quinn DM, Twenge JM. That swimsuit becomes you: sex differences in selfobjectification, restrained eating, and math performance. J Pers Soc Psychol. 1998;75(1):269–84.
71. Nell SM, Fredrickson BL. A mediational model linking self-objectification, body shame and disordered eating. Psychol Women Q. 1998;22:623–36.
72. Tiggemann M, Lynch D. Body image across the life span in adult women: The role of self-objectification. Dev Psychol. 2001;37(2):243–53.
73. Dakanalis A, et al. Objectified body consciousness (OBC) in eating psychopathology. Assessment. 2017;24(2):252–74.
74. Riva G. Out of my real body: cognitive neuroscience meets eating disorders. Front Hum Neurosci. 2014;8:236.
75. Dakanalis A, et al. Psychosocial moderators of the relationship between body dissatisfaction and symptoms of eating disorders: a look at a sample of young Italian women. Eur Rev Appl Psychol. 2013;63(5):323–34.
76. Dakanalis A, et al. Internalization of sociocultural standards of beauty and eating disordered behaviours: the role of body surveillance, shame, and social anxiety. J Psychopathol. 2013;20:33–7.
77. Calogero RM. Objectification processes and disordered eating in British women and men. J Health Psychol. 2009;14(3):394–402.
78. Dakanalis A, Clerici M, Bartoli F, Caslini M, Crocamo C, Riva G, Carra G. Risk and maintenance factors for young women's DSM-5 eating disorders. Arch Womens Ment Health. 2017;11 https://doi.org/10.1007/s00737-017-0761-6.
79. Dakanalis A, et al. body dissatisfaction and eating disorder symptomatology: a latent structural equation modeling analysis of moderating variables in 18-to-28-year-old males. J Psychol. 2015;149(1):85–112.
80. Riva G, Gaudio S, Dakanalis A. I'm in a virtual body: a locked allocentric memory may impair the experience of the body in both obesity and anorexia nervosa. Eat Weight Disord. 2013;19(1):133–4.
81. Gaudio S, Riva G. Body image disturbances in anorexia: the link between functional connectivity alterations and reference frames. Biol Psychiatry. 2013;73(9):e25–6.
82. Riva G, Gaudio S. Allocentric lock in anorexia nervosa: new evidences from neuroimaging studies. Med Hypotheses. 2012;79(1):113–7.
83. Riva G, Dakanalis A. Altered processing and integration of multisensory bodily representations and signals in eating disorders: a possible path toward the understanding of their underlying causes. Front Hum Neurosci. 2018;12:49.
84. Riva G, Gaudio S. Locked to a wrong body: eating disorders as the outcome of a primary disturbance in multisensory body integration. Conscious Cogn. 2018;59:57–9. https://doi.org/10.1016/j.concog.2017.08.006.
85. Luongo MA, Pazzaglia M. Commentary: body image distortion and exposure to extreme body types: contingent adaptation and cross adaptation for self and other. Front Hum Neurosci. 2016;10:526.
86. Eich E, et al. Neural systems mediating field and observer memories. Neuropsychologia. 2009;47(11):2239–51.
87. Eich E, et al. Field and observer perspectives in autobiographical memory. In: Forgas JP, Fiedler K, Sedikides C, editors. Social thinking and interpersonal behavior. New York: Taylor & Francis; 2012. p. 163–81.
88. Juurmaa J, Lehtinen-Railo S. Visual experience and access to spatial knowledge. J Vis Impair Blind. 1994;88:157–70.
89. Kaye WH, Fudge JL, Paulus M. New insights into symptoms and neurocircuit function of anorexia nervosa. Nat Rev Neurosci. 2009;10(8):573–84.
90. Kaye WH, et al. Nothing tastes as good as skinny feels: the neurobiology of anorexia nervosa. Trends Neurosci. 2013;36(2):110–20.

91. Jean A, et al. The nucleus accumbens 5-HTR4-CART pathway ties anorexia to hyperactivity. Transl Psychiatry. 2012;2:e203.
92. Kumar KK, Tung S, Iqbal J. Bone loss in anorexia nervosa: leptin, serotonin, and the sympathetic nervous system. Ann N Y Acad Sci. 2010;1211:51–65.
93. Calati R, et al. The 5-HTTLPR polymorphism and eating disorders: a meta-analysis. Int J Eat Disord. 2011;44(3):191–9.
94. Chen J, et al. The 5-HTTLPR confers susceptibility to anorexia nervosa in Han Chinese: evidence from a case-control and family-based study. PLoS One. 2015;10(3):e0119378.
95. Murray SB, et al. A comparison of eating, exercise, shape, and weight related symptomatology in males with muscle dysmorphia and anorexia nervosa. Body Image. 2012;9(2):193–200.
96. Cafri G, Olivardia R, Thompson JK. Symptom characteristics and psychiatric comorbidity among males with muscle dysmorphia. Compr Psychiatry. 2008;49(4):374–9.
97. Serino S, et al. Virtual reality body-swapping: a tool for modifying the allocentric memory of the body. Cyberpsychol Behav Soc Netw. 2016;19(2):127–33.
98. Serino S, et al. Out of body, out of space: impaired reference frame processing in eating disorders. Psychiatry Res. 2015;230(2):732–4.
99. Riva G. Embodied medicine: what human-computer confluence can offer to health care. In: Gaggioli A, et al., editors. Human computer confluence: transforming human experience through symbiotic technologies. Warsaw: De Gruyter Open; 2016. p. 55–79.
100. Perpiña C, Botella C, Baños RM. Virtual reality in eating disorders. Eur Eat Disord Rev. 2003;11(3):261–78.
101. Ferrer-Garcia M, Gutiérrez-Maldonado J, Riva G. Virtual reality based treatments in eating disorders and obesity: a review. J Contemp Psychol. 2013;43(4):207–21.
102. Riva G. The key to unlocking the virtual body: virtual reality in the treatment of obesity and eating disorders. J Diabetes Sci Technol. 2011;5(2):283–92.
103. Riva G. Medical clinical uses of virtual worlds. In: Grimshaw M, editor. The Oxford handbook of virtuality. New York: Oxford University Press; 2014. p. 649–65.
104. deShazer S. Keys to solutions in brief therapy. New York: W.W. Norton; 1985.
105. Riva G, et al. e-health in eating disorders: virtual reality and telemedicine in assessment and treatment. Stud Health Technol Inform. 2002;85:402–8.
106. Riva G, et al. The use of VR in the treatment of eating disorders. Stud Health Technol Inform. 2004;99:121–63.
107. Riva G, et al. Virtual reality-based multidimensional therapy for the treatment of body image disturbances in obesity: a controlled study. Cyberpsychol Behav. 2001;4(4):511–26.
108. Riva G, et al. Virtual-reality-based multidimensional therapy for the treatment of body image disturbances in binge eating disorders: a preliminary controlled study. IEEE Trans Inf Technol Biomed. 2002;6(3):224–34.
109. Cesa GL, et al. Virtual reality for enhancing the cognitive behavioral treatment of obesity with binge eating disorder: randomized controlled study with one-year follow-up. J Med Internet Res. 2013;15(6):e113.
110. Manzoni GM, et al. Virtual reality-enhanced cognitive-behavioral therapy for morbid obesity: a randomized controlled study with 1 year follow-up. Cyberpsychol Behav Soc Netw. 2016;19(2):134–40.
111. Ferrer-Garcia M, Gutierrez-Maldonado J, Pla-Sanjuanelo J, Vilalta-Abella F, Riva G, Clerici M, et al. A randomised controlled comparison of second-level treatment approaches for treatment-resistant adults with bulimia nervosa and binge eating disorder: assessing the benefits of virtual reality cue exposure therapy. Eur Eat Disord Rev. 2017;25(6):479–90. https://doi.org/10.1002/erv.2538.
112. Pla-Sanjuanelo J, Ferrer-García M, Vilalta-Abella F, Riva G, Dakanalis A, Ribas-Sabaté J, et al. Testing virtual reality-based cue-exposure software: which cue-elicited responses best discriminate between patients with eating disorders and healthy controls? Eat Weight Disord. 2017; https://doi.org/10.1007/s40519-017-0419-4.
113. Ferrer-Garcia M, et al. The validity of virtual environments for eliciting emotional responses in patients with eating disorders and in controls. Behav Modif. 2009;33(6):830–54.

114. Pla-Sanjuanelo J, et al. Identifying specific cues and contexts related to bingeing behavior for the development of effective virtual environments. Appetite. 2015;87:81–9.
115. Dakanalis A, et al. Towards novel paradigms for treating dysfunctional bodily experience in eating disorders. Eat Weight Disord. 2017;22:373–5.
116. Butters JW, Cash TF. Cognitive-behavioral treatment of women's body image satisfaction: a controlled outcome-study. J Consult Clin Psychol. 1987;55:889–97.
117. Wooley SC, Wooley OW. Intensive out-patient and residential treatment for bulimia. In: Garner DM, Garfinkel PE, editors. Handbook of psychotherapy for anorexia and bulimia. New York: Guilford Press; 1985. p. 120–32.
118. Riva G, et al. Virtual reality based experiential cognitive treatment of anorexia nervosa. J Behav Ther Exp Psychiatry. 1999;30(3):221–30.
119. Rinaldi S, et al. La terapia cognitivo-esperienziale: un approccio integrato per la valutazione e il trattamento dei disturbi del comportamento alimentare. Quaderni di Psicoterapia Cognitiva. 1999;4(2):6–21.
120. Cesa GL, et al. Integrated experiential therapy for the treatment of obesity and binge eating disorder: a clinical trial. Cyberpsychol Behav. 2005;8(4):310–1.
121. Riva G, et al. Virtual reality environment for body image modification: a multidimensional therapy for the treatment of body image in obesity and related pathologies. Cyberpsychol Behav. 2000;3(3):421–31.
122. Riva G, et al. Virtual reality based experiential cognitive treatment of obesity and binge-eating disorders. Clin Psychol Psychother. 2000;7(3):209–19.
123. Serino S, Chirico A, Pedroli E, Polli N, Cacciatore C, Riva G. Two-phases innovative treatment for anorexia nervosa: the potential of virtual reality body-swap. Annu Rev Cyberther Telemed. 2017;15:111–5.
124. Keizer A, et al. A virtual reality full body illusion improves body image disturbance in anorexia nervosa. PLoS One. 2016;11(10):e0163921.
125. Serino S, Scarpina F, Keizer A, Pedroli E, Dakanalis A, Castelnuovo G, Chirico A, Novelli M, Gaudio S, Riva G. A novel technique for improving bodily experience in a non-operable super-super obesity case. Front Psychol. 2016;7:83.
126. Gutierrez-Maldonado J, et al. Virtual reality: applications to eating disorders. In: Agras SW, Robinson A, editors. The Oxford handbook of eating disorders. 2nd ed. Oxford: Oxford University Press; 2017. p. 146–61.
127. Riva G, et al. Embodied medicine: mens sana in corpore virtuale sano. Front Hum Neurosci. 2017;11:120.
128. Preston C, Ehrsson HH. Illusory changes in body size modulate body satisfaction in a way that is related to non-clinical eating disorder psychopathology. PLoS One. 2014;9(1):e85773.
129. Preston C, Kuper-Smith BJ, Henrik Ehrsson H. Owning the body in the mirror: the effect of visual perspective and mirror view on the fullbody illusion. Sci Rep. 2015;5:18345.
130. Preston C, Ehrsson HH. Illusory obesity triggers body dissatisfaction responses in the insula and anterior cingulate cortex. Cereb Cortex. 2016;26(12):4450–60.
131. Marco JH, Perpina C, Botella C. Effectiveness of cognitive behavioral therapy supported by virtual reality in the treatment of body image in eating disorders: One year follow-up. Psychiatry Res. 2013;209(3):619–25.