12 Virtual Reality

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Key Points

- Virtual reality (VR) technology is an integrated experiential platform able to engage obese individuals in mastering physical activity, diet, and self-regulatory strategies—targeting both emotions and experience of the body.
- It provides a safe environment for learner experimentation, real-time personalized behavioral weight management tasks, and strategies.
- It is able to target negative emotions and body image dissatisfaction that play a critical role in the onset and maintenance of this disorder.
- It has the potential of improving treatment adherence, addressing a critical issue to achieve successful weight loss and weight maintenance.

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12.1 Introduction

The evolution of technology is providing new tools and methods for health care [1]. Between them, an emerging trend is the use of virtual reality (VR) [2–4].

Computer scientists define VR as a set of fancy technologies used to create a simulated environment [5]: an interactive 3D visualization system (a computer, a game console, or a smartphone) supported by one or more position trackers and head-mounted display. The trackers sense the movements of the user and report them to the visualization system which updates the images for display in real time.

However, psychology and neuroscience define VR as [6] "an advanced form of human-computer interface that allows the user to interact with and become immersed in a computer-generated environment in a naturalistic fashion" (p. 82). In fact, from a cognitive viewpoint, VR is mainly a *subjective experience* that makes the user believe that he/she is there, that the experience is real [7]. Why? As underlined recently [8, 9], VR shares with our brain the same basic mechanism: embodied simulations. According to neuroscience our brain, to effectively regulate and control the body in the world, creates an embodied simulation of the body in the world used to represent and predict actions, concepts, and emotions. VR works in a similar way: the VR experience tries to predict the sensory consequences of the individual's movements providing to him/her the same scene he/she will see in the real world. This transforms VR into an experiential technology that is able to target at the same time both the body and the mind.

As underlined by two different meta-reviews [7, 8] discussing 48 different systematic reviews and meta-analyses, VR is a powerful clinical tool for behavioral health, able to provide assessment and effective treatment options for different mental health problems. Specifically, VR compares favorably to existing treatments in anxiety disorders, eating and weight disorders, and pain management, with long-term effects that generalize to the real world. Moreover, they show the potential of VR as an assessment tool with practical applications that range from social and cognitive deficits to addiction. Finally, they suggest a clinical potential in the treatment of psychosis and in the pediatric field.

In this chapter we focus our analysis to the field of obesity, discussing the potential of VR to achieve successful weight loss and weight maintenance [10–13]. In particular we discuss three different applications of VR in this field: exergames, emotion regulation, and multisensory integration.

12.2 VR for Exergames

The term "exergames," the fusion of the words "exercise" and "gaming," indicates video games that provide also a form of exercise. As explained by Rizzo and colleagues [13]: "The core concept of exergaming rests on the idea of using vigorous body activity as the input for interacting with engaging digital game content with the hope of supplanting the sedentary activity that typifies traditional game interaction that relies on keyboards, gamepads, and joysticks." (p. 259).

By creating engaging digital gaming interacted via body movements, the motivation to participate in calorie-burning cardiovascular exercise activities is increased. In particular, the three factors influencing motivation and compliance [14]—feedback, challenge, and rewards—are all supported by virtual reality experiences.

Feedback is a critical part of physical exercise because it offers informative and evaluative feedback on skill development and progress, allowing the perceptions of competence and the identification of possible errors or shortcomings. Typically feedbacks can be visual, auditory, or sensory, but in VR their integration and multiple use are possible: for example, a progress bar with the remaining time and tasks, physical indications in the player avatar (stumbling, showing a slower pace, etc.), a sound to indicate the amount of exercise left, and other avatars (e.g., the virtual coach) commenting on the performance.

According to the theory of "flow" introduced by Csikszentmihalyi [15, 16] an optimal match between skill and challenge is critical to achieve an intrinsically motivating experience. In this view, the ability of the exergame to assess the skill of the user and to provide a level of challenge matched to it is required to guarantee compliance and motivation. VR facilitates this process. Using VR it is possible to develop exergames in which subjects experience themselves as competent and efficacious [5, 17]. Specifically, the VR experience can offer different difficulty levels—from easy tasks to very difficult ones—offering a controlled setting in which the individual is able to develop new skills through trials and errors. Using this approach, the level of challenge can be balanced to the skill of the user so that failures can support perceived relatedness and competence without reducing perceived competence [14].

The final component for the success of exergames is reward. It is well known that external rewards support behavior as long as the rewards are present, but intrinsically motivated activity is more likely to produce long-term change [18]. Again, VR supports the provision of effective reward, by allowing two different types of reward [14]: controlling rewards that are task and performance contingent and autonomy-supportive rewards that are verbal and task noncontingent. In particular, it allows the use of embodiment as a form of autonomy-supportive reward through specific poses and ballets that can be replicated and shared by users. Differently by non-VR videogames, the use of embodied avatars with normal body size has the potential to increase the effectiveness of exergames among overweight children as demonstrated by a recent study [19].

These principles have been used in different successful exergames [20–23]. For example, Astrojumper is an immersive virtual reality exergame used to engage children and adults in rigorous, full-body exercise [20]. The overall goal of this exergames is relatively easy: users fly through an immersive, stereoscopic outer space environment in first-person perspective and they have to avoid or grab the different virtual planets that are speeding toward them. As the authors explain [20]: "To make sure that Astrojumper would be playable for users at all levels of physical fitness, Astrojumper begins very slowly, providing all users with a warm-up phase. After this phase is complete, planets will begin to gradually come out at a slightly faster rate. If the player is successfully able to avoid these planets, the speed will continue to increase. If the player starts to collide with the planets, their speed will reduce. This back-and-forth adjustment finds a speed where the player can successfully avoid almost all of the planets, and will continuously update throughout the game." (p. 87).

The achieved results support this approach. A study involving 30 subjects (10 participants were children and 20 were adults) demonstrated that Astrojumper is an effective way to provide a workout, motivating both children and adults to exercise through immersive VR [20].

Up to now the most significant barrier to the wide use of VR exergames is cost [22]. However, the appearance of cheaper stand-alone VR devices (see Table 12.1) associated to successful commercial VR exergames like Beat Saber or Dance Central may improve the use of this approach in the prevention and treatment of obesity.

12.3 VR for Emotion Regulation

Stress and negative emotions have been shown to be critical factors in inducing overeating as a form of maladaptive coping in some patients with obesity. According to the theory of emotional eating [24], eating is used as a strategy to regulate or escape negative emotions and it is related to both obesity and binge eating disorders. Specifically, Macht identified five classes of emotion-induced changes of eating [24]: (1) emotional control of food choice, (2) emotional suppression of food intake, (3) impairment of cognitive eating controls, (4) eating to regulate emotions, and (5) emotion-congruent modulation of eating. Different studies suggest the ability of VR to address many of them.

First, using VR is possible to modulate food craving, the intense desire to consume a specific food (selective hunger). According to Jansen [25] once eating behavior has been established, exposure to specific food cues—i.e., cues systematically associated with food intake such as the presence of high-calorie food—induces a conditioned response (hyperinsulinemia), which thus activates a hypoglycemic compensatory response. This biochemical response is experienced as food craving and may lead to an eating episode. However, by exposing participants to these cues, cue exposure therapy is designed to progressively break the mental links that typically precede using. For example, in cue exposure therapy (CET), an obese individual may be exposed to a chocolate cake or any other high-calorie food. Initially, the exposure to the cue prompts the brain to "expect" consumption. However, frequent exposure to different cues—without eating—reduces the likelihood of a cue-induced eating in the future by desensitizing the brain's reaction.

VR is perfect for CET. On one side, as demonstrated by Gorini and colleagues [26], real food and virtual food induced a comparable emotional reaction in patients that is higher than the one elicited by photos of the same food. More, unlike exposure to photographs, in vivo exposure, and guided imagination, VR offers a good ecological validity, and also a fair internal validity, while allowing strict control over the variables. This is true also for social interactions in VR. As demonstrated by Balzarotti and colleagues [27], VR avatars are recognized as intentional agents and users adjust their emotion nonverbal behavior according to the behavior of the

Table 12.1 Commercial VR devices

	PC based			Mobile based			Console based	Stand-alone		
System	Oculus Rift	HTC Vive/ Vive Pro	Microsoft Mixed Reality	Samsung Gear VR	Google Cardboard	Google Daydream	Playstation VR	Oculus Go	Oculus Quest	Mirage Solo
Cost	399 US$	499/799 US$	249/449 US$	99 US$	10–50 US$	69–149 US$	299 US$	199 US$	399 US$	299 US$
Hardware requirements	High-end PC (>1000 US$)	High-end PC (>1000 US$)	Mid-level PC (>600 US$)	High-end Samsung phone (>600 US$)	Middle/ high-end Android phone or iPhone (>299 US$)	High-end Android phone (>499 US$)	PS4 (299 US$) or PS4 Pro (399 US$)	None (Internal Snapdragon 821 processor)	None (Internal Snapdragon 835 processor)	None (Internal Snapdragon 835 processor)
Resolution	2160 × 1200	2160 × 1200/2880 × 1660	2880 × 1440	2560 × 1440	Depends on the phone (minimum 1024 × 768)	Depends on the phone (minimum 1920 × 1080)	1920 × 1080	2560 × 1440	2560 × 1440	2560 × 1440
Refresh rate	90 Hz	90 Hz	90 Hz	60 Hz	60 Hz	90 Hz minimum	120 Hz	72 Hz	72 Hz	75 Hz
Field of view	110°	110°	100/110°	101°	From 70°	96°	100°	90°	100°	100°
Body tracking	Medium/ high: Head tracking (rotation) and positional tracking (forward/ backward)	High: Head tracking (rotation) and volumetric tracking (full room size—15 ft × 15 ft—movement)	Medium/ high: Head tracking (rotation) and positional tracking (forward/ backward)	Medium: Head tracking (rotation)	Medium: Head tracking (rotation)	Medium: Head tracking (rotation)	Medium/ high: Head tracking (rotation) and positional tracking (forward/ backward)	Medium: Head tracking (rotation)	Medium/ high: Head tracking (rotation) and positional tracking (forward/ backward)	Medium/ high: Head tracking (rotation) and positional tracking (forward/ backward)

(continued)

Table 12.1 (continued)

	PC based			Mobile based			Console based	Stand-alone		
User interaction with VR	High (using a joystick or controllers)	High (using controllers)	High (using a joystick or controllers)	Medium (using gaze, a built-in pad, or joystick)	Low (using gaze or a button)	Medium (using gaze or joystick)	High (using a joystick or controllers)	Medium (using gaze, a built-in pad, or joystick)	High (using a joystick or controllers)	Medium (using gaze, a built-in pad, or joystick)
Software availability	Oculus Store	Steam Store	Microsoft Store	Oculus Store	Google Play or IOS Store	Google Play	Playstation Store	Oculus Store	Oculus Store	Google Play

avatar. On the other side, several studies support the ability of food-related VR environments to induce food craving [28, 29].

Their results [30] suggest that craving experienced in VR environments incorporating cues and contexts related to binging behavior was consistent with trait and state craving assessed (with questionnaires) outside the VR environments. In addition, participants with the highest scores on trait and state craving also experienced craving when exposed to food in VR. Finally, scores on questionnaires assessing trait and state craving were able to predict the average craving experienced in VR.

These results provide a clear rationale for the use of VR-CET with eating-disordered patients. And different studies are providing an experimental support to this claim.

A first study assessed the efficacy of CET based on VR (VR-CET) as a second-level treatment in patients with bulimia nervosa (BN) and binge eating disorders [31]. With this objective in mind, 64 patients diagnosed with BN or BED, according to DSM-5 who were treatment resistant (that is, their binges persisted after CBT), were randomly assigned to one of the two booster session conditions: a VR-CET booster sessions group, and a CBT booster sessions group (the control group).

Booster sessions consisted of six 60-min sessions held twice weekly over a period of 3 weeks. Over the six sessions, participants in the experimental group were exposed to different VR environments related to binge behavior, according to a previously constructed hierarchy. During exposure, patients faced high-risk situations and handled the virtual foods using a computer mouse. Exposure ended after a significant reduction in the level of anxiety, or after 60 min. Participants in the control group received six CBT booster sessions to improve treatment outcome.

A significant interaction between group (VR-CET vs. CBT) and time (before and after booster sessions) was expected, showing the maintenance of the number of binges and purges before and after booster sessions in the control group (CBT) and a reduction in the experimental group (VR-CET).

After the six booster sessions, patients in both CBT and VR-CET conditions presented improvement. However, participants in the VR-CET group showed significantly higher reductions in binges, purges, bulimia symptoms (assessed with the Bulimia scale of the Eating Disorders Inventory-3; EDI-3), craving for food (assessed with the Food Craving Questionnaire-State/Trait; FCQ-S/T), and anxiety (State and Trait Anxiety Inventory, STAI) than patients in the CBT group. A follow-up study showed that the VR-CET group maintained the obtained results also after 6 months [32]. Moreover the obtained reductions were greater after VR-CET, regarding binge and purge episodes, as well as the decrease of self-reported tendency to engage in overeating episodes.

In sum, these results support the use of VR-CET as an effective way for reducing food craving and related behaviors in eating- and weight-disordered individuals.

Second, VR can also be used to improve emotion regulation. In a different study Manzoni and colleagues [33] evaluated the efficacy of a 3-week relaxation protocol enhanced by VR in reducing emotional eating in a sample of 60 female inpatients with obesity who report emotional eating. To reach this goal they used a three-arm exploratory randomized controlled trial with 3 months of follow-up. The intervention included 12 individual relaxation training sessions provided traditionally (imagination condition) or supported by virtual reality (virtual reality condition). Control participants received only standard hospital-based care. Their data show that VR-enhanced relaxation training was effective in reducing emotional eating episodes and depressive and anxiety symptoms, and in improving perceived self-efficacy for eating control at 3-month follow-up after discharge. The virtual reality condition proved better than the imagination condition in the reduction of emotional eating. Weight decreased in subjects in all three conditions without significant differences between them, probably due to the common treatment all inpatients received. In conclusion, VR-enhanced relaxation training is a useful tool for reducing emotional eating episodes and thereby reducing weight and obesity.

12.4 VR for Improving Multisensory Integration

In our culture most women are dissatisfied with their body: one adolescent girl out of two reports body dissatisfaction [34]. And recent studies highlighted that sociocultural pressure to be thin is central to the development of negative feelings about the body, which are recognized as critical risk factor for the emergence of overweight and obesity [35–37].

A first longitudinal study [37] used data from a prospective study of 496 adolescent girls who completed a baseline assessment at age 11–15 years and four annual follow-ups to test whether behavioral and psychological risk factors predict the onset of obesity during adolescence and to compare the predictive power of these factors with that of parental obesity. Contrary to hypotheses, elevated intake of high-fat foods, binge eating, and exercise did not predict obesity onset. Instead the most important predictor was elevated dietary restraint scores associated to maladaptive compensatory behaviors for weight control, such as vomiting or laxative abuse.

Moreover, a second study [35] tried to identify 10-year longitudinal predictors of overweight incidence during the transition from adolescence to young adulthood using a population-based cohort ($N = 2134$). At 10-year follow-up, 51% of young adults were overweight (26% increase from baseline). Among females and males, higher levels of body dissatisfaction, weight concerns, unhealthy weight control behaviors (e.g., fasting, purging), dieting, binge eating, weight-related teasing, and parental weight-related concerns and behaviors during adolescence and/or increases in these factors over the study period predicted the incidence of overweight at 10-year follow-up.

Finally, a third longitudinal study [36] explored whether weight-based teasing in adolescence predicts adverse eating and weight-related outcomes 15 years later. The results are quite clear: weight-based teasing in adolescence predicted higher BMI and obesity 15 years later. For women, these longitudinal associations occurred across peer- and family-based teasing sources, but for men, only peer-based teasing predicted higher BMI.

For this reason, the “objectification theory” suggests a significant role of culture and society in the etiology of eating and weight disorders. Introduced by Fredrickson and Roberts [38], this theory suggests that our culture imposes a specific self-evaluation model—self-objectification—defining women’s behavioral and emotional responses [39–41]. At its simplest, the objectification theory holds that [1] there exists an objectified societal ideal of beauty (within a particular culture) that is [2] transmitted via a variety of sociocultural channels. This ideal is then [3] internalized by individuals, so that [4] satisfaction (or dissatisfaction) with appearance will be a function of the extent to which individuals do (or do not) meet the ideal prescription [42].

The internalization of an observer's perspective on one's own body is labeled as "self-objectification" [43, 44] and reduces a woman's worth to her perception of her body's semblance to cultural standards of attractiveness [45].

Even if self-objectification can be a critical risk factor for the development of obesity and overweight through its link with teasing, body image dissatisfaction, and unhealthy weight control behaviors the objectification theory is still not able to answer two critical questions [46]: Why do not all the individuals experiencing self-objectification develop EDs? What is the role of the body experience in the etiology of obesity?

Here we will embrace an emerging field of neuroscience—the multisensory integration of bodily representations and signals [47, 48]—to answer the above questions.

Multisensory body integration is a critical cognitive and perceptual process, allowing the individual to protect and extend his/her boundaries at both the homeostatic and psychological levels [49, 50]. To achieve this goal the brain integrates sensory data arriving from real-time multiple sensory modalities and internal bodily information with predictions made using the stored information about the body from conceptual, perceptual, and episodic memory. In this view the emotional [51], motor [52], proprioceptive [53], and interoceptive [54] deficits reported by many authors in individuals with obesity may reflect a broader impairment in multisensory body integration [55]. Specifically it can affect the individual's abilities [47, 48]: (a) to identify the relevant interoceptive signals that predict potential pleasant (or aversive) consequences and (b) to modify/correct the autobiographical allocentric (observer view) memories of body-related events (self-objectified memories).

The first effect of an impaired multisensory body integration is a prospective aversive body state [56]. This situation makes it difficult for obese individuals to obtain and regulate a sense of self and could contribute to the problems with body image and self-disturbances.

The second effect of an impaired multisensory body integration is that obese 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 [57, 58]. Therefore, successful dieting attempts are not able to improve body dissatisfaction and subjects may either start more radical dieting attempts or, at the opposite end, engage in "disinhibited" eating behaviors [44].

VR allows to target an impaired multisensory body integration through two different strategies—"reference frame shifting" [59, 60] and "body swapping" [61, 62]—that can be integrated within a classical cognitive-behavioral training (CBT) for obesity.

The first method, "reference frame shifting" [59, 60], structures the individual's bodily self-consciousness (see Table 12.2) through the focus and reorganization of its contents [60, 63].

Table 12.2 The VR body image rescripting protocol (adapted from Riva, 2011)

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 the VR development toolkit.
Phase 3: Egocentric 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 was needed to happen to change the feelings in a positive direction. The main cognitive techniques used in this phase, if needed, are: *Countering*: Once a list of distorted perceptions and cognitions is developed, the process of countering these thoughts and beliefs begins. *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: Allocentric 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 both to calm and reassuring his/her virtual avatar and to counter any negative evaluation. The therapist follows 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: *Alternative interpretation*: The patient learns to stop and consider other interpretations of a situation before proceeding to the decision-making stage. *Deactivating the illness belief:* The therapist first helps the client list her beliefs concerning weight and eating.

To achieve it, the subject re-experiences in VR a negative situation related to the body (e.g., teasing) both in first person and in third person (e.g., seeing and supporting his/her avatar in the VR world) integrating the therapeutic methods used by Butters and Cash [64] and Wooley and Wooley [65]. Specifically, the VR situations are used in the same way as guided imagery [66] is used in the cognitive and visual/motorial approach. In general, the therapist asks the patient to give detailed descriptions of the virtual experience and of the feelings associated with it. Furthermore, the patient is taught how to cope with them [66].using different techniques (see Table 12.2).

This approach has been successfully used in different randomized trials with obese patients [67, 68] allowing both to update the contents of their body memory and to improve the clinical outcomes over traditional CBT.

In the second—"body swapping" [61, 62]—VR is used to induce the illusory feeling of ownership of a virtual body with a different shape and/or size. Since the publication by Botvinick and Cohen [69] revealing that it is simple to generate in people the illusion that a rubber hand is part of their body (rubber hand illusion—RHI), there has been increasing research interest in the study of bodily illusions.

Specifically, this term refers to controlled illusory generation of unusual bodily feelings, such as the feeling of ownership over a rubber hand that affects the experience of a body part or the entire body (i.e., a body-swap illusion).

More recently, an increasing body of pioneered research conducted by Riva team [70, 71] revealed that the embodiment in a virtual body that substitutes the own body in virtual reality with visuo-tactile stimulation (body-swap illusion) alters body percept (i.e., participants are significantly fatter or thinner than they really are) suggesting, among others, that virtual reality is more than a way of placing people in a simulated world (i.e., manipulating their sense of place).

A first study [70] has showed that the body-swap illusion is able to induce an update of the negative stored representation of the body. In particular, it has been found that after embodying a virtual body with a skinny belly there was an update of the "remembered body," with women reporting a significant (post-illusion) decrease in their body-size distortion. Consistent with this perspective, Preston and Ehrsson [72] induced an illusory ownership over a slimmer mannequin by synchronously stroking the mannequin body and the corresponding part of the participants' body. It has been found that that the illusory ownership over a slimmer body decreases significantly participants' perceived body size but also increases significantly participants' body satisfaction.

Support for the use of bodily illusions to alter the dysfunctional experience of the body in obesity comes from a recent published study [71]. Serino and colleagues showed that a (virtual reality) 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 patient's motivation to maintain healthy eating behaviors. While no studies to date have directly exploited the capability of the bodily illusions in obese treatment, the evidence deriving from the extant experimental studies for a (a) direct link between perceptual (described as an inability to accurately estimate body size) and affective (described as subjective body dissatisfaction) body-image components and (b) a positive affective response with the body illusion-modulated severe obesity [71] may suggest clinical applications for these methods.

12.5 Conclusions

Most clinicians and patients consider obesity just as a problem of energy input and expenditure: more energy input than expenditure. However, the clinical practice and epidemiological data clearly show that obesity is more complex than expected by this simple equation.

In this chapter we underlined significant potential of VR in this process by discussing three different applications of VR: exergames, emotion regulation, and multisensory integration.

The term "exergames," the fusion of the words "exercise" and "gaming," indicates digital experiences that provide also a form of exercise able to increase the motivation to participate in calorie-burning cardiovascular activities. In particular, VR is able to support the three factors influencing motivation and compliance [14]—feedback, challenge, and rewards—with different studies supporting its clinical efficacy. Up to now the most significant barrier to the wide use of VR exergames is cost [22]. However, the appearance of cheaper stand-alone VR devices (see Table 12.1) associated to successful commercial VR exergames may improve the use of this approach in the prevention and treatment of obesity.

Stress and negative emotions have been shown to be critical factors in inducing overeating as a form of maladaptive coping in some patients with obesity. Different studies suggest the ability of VR to address many of them.

First, using VR is possible to modulate food craving, the intense desire to consume a specific food (selective hunger) and related behaviors in eating- and weight-disordered individuals. Moreover, VR-enhanced relaxation training is a useful tool for reducing emotional eating episodes and thereby reducing weight and obesity.

Other critical risk factors for the emergence of overweight and obesity are that sociocultural pressure to be thin is central and the development of negative feelings about the body, in particular self-objectification [35–37]. When these factors are associated to an impaired multisensory body integration they produce a paradoxical situation [57, 58]: obese 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. Therefore, successful dieting attempts are not able to improve body dissatisfaction and subjects may either start more radical dieting attempts or, at the opposite end, engage in "disinhibited" eating behaviors [44]. VR is able to correct an impaired multisensory body integration through two different strategies—"reference frame shifting" [59, 60] and "body swapping" [61, 62]—that can be integrated within a classical cognitive-behavioral training (CBT) for obesity. If the first strategy is already backed by different randomized controlled trials with obese patients [67, 68], no randomized studies to date have directly exploited the capability of the bodily illusions in obese treatment. However, the evidence deriving from different basic research studies and the result of a case study [71] may suggest clinical applications for this method, too.

In conclusion, the available clinical data suggest the added value of VR as part of an integrated obesity treatment targeting both the physical and the psychological side of the problem. Longer follow-up data and multicentric trials are required to investigate the possible effects of the behavioral, emotional, and body image changes on the long-term maintenance of the weight loss.

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