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Using avatars in weight management settings: A systematic review

M. Horne[a,*], A. Hill[b], T. Murells[c], H. Ugail[d], Irving[e], R. Chinnadorai[f], M. Hardy[g]

[a] Faculty of Medicine and Health, School of Healthcare, University of Leeds, Leeds LS1 9JT, UK
[b] Faculty of Medicine and Health, University of Leeds, Leeds LS1 9JT, UK
[c] Florence Nightingale Faculty of Nursing, Midwifery & Palliative Care, King's College London, London WC2R 2LS, UK
[d] Centre for Visual Computing, University of Bradford, Bradford BD7 1DP, UK
[e] Faculty of Medicine and Health, Academic Unit of Health Economics, University of Leeds, Leeds LS19JT, UK
[f] The Mid Yorkshire Hospitals NHS Trust, Pinderfields Hospital, Wakefield WF1 4DG, UK
[g] Faculty of Health Studies, University of Bradford, Bradford BD7 1DP, UK

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ABSTRACT

Background: Obesity interventions rely predominantly on managing dietary intake and/or increasing physical activity but sustained adherence to behavioural regimens is often poor. Avatar technology is well established within the computer gaming industry and evidence suggests that virtual representations of self may impact real-world behaviour, acting as a catalyst for sustained weight loss behaviour modification. However, the effectiveness of avatar technology in promoting weight loss is unclear.

Aims: We aimed to assess the quantity and quality of empirical support for the use of avatar technologies in adult weight loss interventions.

Method: A systematic review of empirical studies was undertaken. The key objectives were to determine if: (i) the inclusion of avatar technology leads to greater weight loss achievement compared to routine intervention; and (ii) whether weight loss achievement is improved by avatar personalisation (avatar visually reflects self).

Results: We identified 6 papers that reported weight loss data. Avatar-based interventions for weight loss management were found to be effective in the short (4–6 weeks) and medium (3–6 months) term and improved weight loss maintenance in the long term (12 months). Only 2 papers included avatar personalisation, but results suggested there may be some added motivational benefit.

Conclusions: The current evidence supports that avatars may positively impact weight loss achievement and improve motivation. However, with only 6 papers identified the evidence base is limited and therefore findings need to be interpreted with caution.

1. Introduction

1.1. Background

Obesity remains a global public health concern (WHO, 2016). In 2016, over 650 million adults worldwide were classified as obese (BMI ≥ 30 kg/m2) (WHO, 2018) and in England, 26% of adults were considered obese (Health and Social Care Information Centre, 2017), a proportion similar to reported societal obesity levels across the developed world (OECD, 2017).

Obesity is associated with a range of increased health risks including diabetes (type II), heart disease, cancer (Lauby-Secretan et al., 2016), depression and mental health issues (Rajan and Menon, 2017; McPherson et al., 2007), all of which may impact upon societal engagement and quality of life (Wang et al., 2011). Obesity also increases demand for, and complexity of, healthcare services and is estimated to cost the National Health Service (NHS) £5bn annually (Scarborough et al., 2011; McPherson et al., 2007) with a projected increase of £1.9-£2bn per annum by 2030 without intervention (Yanovski and Yanovski, 2014). Consequently, in terms of individual, societal and economic well-being and sustainability, developing effective interventions to reduce population obesity is imperative.

Obesity interventions in adults rely predominantly on managing dietary intake and/or increasing physical activity (Shaw et al., 2005). More recently, bariatric surgery has been offered as a last resort weight loss intervention (NICE, 2014) as evidence suggests this is more effective than either pharmacological or lifestyle interventions for moderately to severely obese people (Picot et al., 2009). However, bariatric surgery is not a weight loss intervention in itself, but a surgical procedure that is undertaken alongside behaviour change interventions

* Corresponding author.
E-mail address: m.horne@leeds.ac.uk (M. Horne).

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and requires the adoption of healthy lifestyle behaviours for long term maintenance of weight reduction (Faria et al., 2010). As with all interventions or treatments, the lack of sustained motivation, self-efficacy (a belief in one's ability to undertake the intervention) and poor adherence to behavioural regimens (Coons et al., 2012; Rosser et al., 2009) are acknowledged to be barriers to successful weight loss (Faria et al. 2010). To address this, weight management interventions are increasingly using digital technologies (Holmes et al., 2018; Raajimakers et al., 2015; Bacigalupo et al., 2013; Khaylis et al., 2010) or mobile applications (Mateo et al., 2015) to support weight loss. Dedicated mobile phone applications have shown some promise with a systematic review and meta-analysis suggesting their use produces a small (1.04 kg), but statically significant additional weight loss over and above that achieved by a control group (Mateo et al., 2015). However, despite their promotion, < 20% of the persons using aids to assist weight management in England reported using digital technologies (wearable trackers, mobile phone applications or websites). As a result, questions have been raised over population enthusiasm to engage with such technology along with suggestions that greater motivational digital technologies are required to support losing weight (Solbrig et al., 2017).

Virtual reality (VR) enables people to experience an alternate visual reality, often through an avatar (computerised representation of self). Avatar technology is well established within the computer gaming industry and third person perspective of self within a VR setting has been shown to promote emotional engagement (Schuurink and Toet, 2010; Sohye and Reeves, 2009). Research has also demonstrated a link between a virtual representation of self and real-world behaviours (Wrzesien et al., 2015; Seitz et al., 2014; Behm-Morawitz, 2013; Fox et al., 2013; Bordnick et al., 2011; Fox et al., 2009) as a result of individuals identifying with their avatar (Schultze and Leahy, 2009) and experiencing presence within the computer mediated environment (Parrish et al., 2015; Ganesh et al., 2012). Consequently, immersion in and engagement with, the VR environment may promote changes in health behaviour (Ahn, 2015) and it has been suggested as a potential behaviour modification tool for addressing obesity (Napolitano et al., 2013; Fox and Bailenson, 2009). Studies undertaken within an experimental environment have demonstrated that an individual's behaviour conforms to their digital self-representation (Bordnick et al., 2011; Fox et al., 2013; Yee and Bailenson, 2007). Further, research suggests that observing a self-resembling avatar, as opposed to a generic avatar, modelling a particular behaviour/activity (e.g. exercise) within a VR environment differentially and positively influences real world behaviour and increases engagement with the modelled activity (Behm-Morawitz, 2013; Yee et al., 2009). Avatar personalisation, therefore, may have additional potential within digital weight loss interventions.

1.2. Research goal and aims

To our knowledge there is no systematic review considering the effectiveness of avatar based digital technologies on weight loss outcomes. Previous identified reviews have focussed on VR in rehabilitation (Rose et al., 2018; Howard, 2017; Laver et al., 2017); digital chronic pain management through personification of an e-coach or online therapist in the form of an avatar (Traynor et al., 2016) and gamification for health and wellbeing (Sardi et al., 2017; Johnson et al., 2016). The aim of this review was to assess the quantity and quality of empirical support for the use of avatar technologies in adult weight loss interventions and determine if: (i) the inclusion of avatar technology leads to greater weight loss achievement compared to routine interventions; and (ii) whether weight loss achievement is improved by avatar personalisation (self-resembling avatar).

2. Methods

The protocol and focus for the review was developed and agreed by the authors prior to commencement. To ensure all relevant papers were identified, a health information specialist conducted a systematic search of the literature databases using established standards (Centre for Reviews and Dissemination (CRD), 2009; Higgins and Green, 2011) in August 2017, August 2018 and July 2019. The PRISMA guidance was used to inform both the conduct and reporting of the review (Moher et al., 2009).

2.1. Data collection

The databases searched included those considered relevant to weight loss, health interventions, population or public health and digital technologies. Full holdings of the following nine electronic databases were searched: AMED, CINAHL, Embase, IEEE, MEDLINE, PsycINFO, Cochrane Central Trials Register of Controlled Trials (CENTRAL), Science Direct and Scopus. Searches were limited to studies published from 2000 to July 2019 in English. Additional articles were identified by searching the references of included articles.

2.2. Search terms

Search terms were developed under the headings "Obesity", "Avatar" and "Decision making", with decision making including broader concepts, such as autonomy, choice and commitment. Truncation (*) was employed where variations of a search term existed. Additional broad search terms were used to ensure that all studies meeting the inclusion criteria were captured. Keywords included combinations of "weight loss", "Body Mass Index", "diet", "compliance", "adherence", "self-efficacy", virtual world", "virtual reality", "second life" and "virtual environment". A copy of the search terms used and modifications necessary across databases is available from the corresponding author upon request.

2.3. Inclusion/exclusion criteria

Papers were included where they reported the results of empirical research where participants were overweight or obese adults (aged 18+ years); the weight management intervention included an avatar technology; and weight (self-reported or measured) was reported as a numerical value pre and post intervention. Research papers were excluded where any of these criteria were unmet.

2.4. Quality assessment & data extraction

Quality of study design, including methods selection, identification of biases, appropriate use of statistical methods, and clarity of reporting was assessed using a validated checklist for evaluating studies of diverse designs developed by Sirriyeh et al. (2012). Study eligibility was confirmed by two authors with mitigation by a third where disagreements arose. Each paper was judged against 14 points on the checklist, where a single method was used, and 16 points on the checklist, where multi methods were used. A percentage score was calculated as a measure of quality. Studies achieving scores of < 50% were considered poor quality; those with scores between 50 and 70% were considered to be moderate quality; and those with scores of > 70% were considered high quality.

Extracted data included socio-demographic characteristics of participants; country of origin; sample size; intervention/control description; weight change; other relevant intervention outcomes such as self-efficacy, motivation, experience and/or engagement with weight-loss programme and avatar technology.

2.5. Synthesis

Due to the small number of studies that met the inclusion criteria and heterogeneity in study design, intervention and outcome measures,

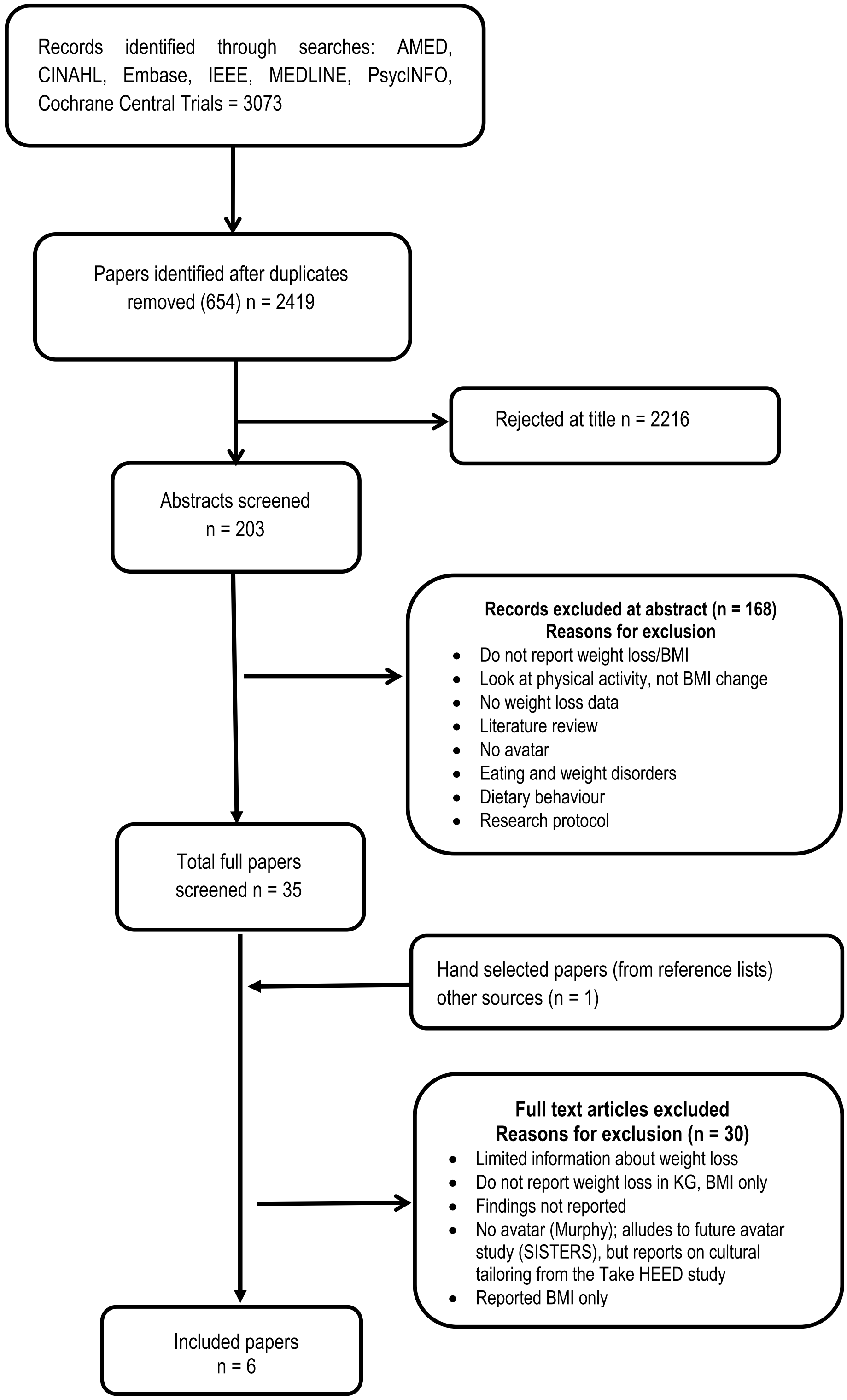

Fig. 1. PRISMA flow diagram of study selection here.

meta-analysis was not possible and a narrative synthesis was performed (Petticrew and Roberts, 2006).

3. Results

The study selection process is illustrated in Fig. 1. Initial database searches returned 2419 hits (excluding duplicates), of which six papers (Behm-Morawitz et al., 2016; Cesa et al., 2013; Johnston et al., 2012; Manzoni et al., 2016; Napolitano et al., 2013; Ossolinski et al., 2017) met the criteria for inclusion. Key study key characteristics and quality ratings are also outlined in Table 1.

3.1. Quality of studies

All included papers were of moderate or high quality (Table 1) ranging in scores from 57% (Johnston et al., 2012) to 88% (Cesa et al.,

Table 1
Characteristics of included studies.

Immersive Virtual Environments (IVE)
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Behm-Morawitz et al. (2016) USA	3 arm RCT. To examine the effects of virtual embodiment & play in a social virtual world (Second Life [SL]) for increasing health self-efficacy (exercise & nutrition efficacy) among overweight Adults.	4 week programme. Start interview participants completed surveys, body measurements taken & instructions provided. At week 4, same measures taken plus open ended questions about experiences in the study. At week 2 survey was emailed to participants to keep them engaged but this was not used in the analysis. Participants were randomly assigned to one of three conditions: (i)3D social virtual world (avatar virtual interaction. Experimental condition) (ii) 2D social networking site (no avatar virtual interaction control condition). (iii) no intervention (no virtual interaction control condition). (i) Avatar virtual intervention participants were instructed to use SL for a minimum of two times/week (totalling 2 h/week) for the duration of the study. Participants visited a list of in world locations that promoted physical activities, such as yoga, weightlifting, snowboarding & surfing. In week 1: participants were taught to use SL & navigate to the Avatar Fitness Club to practice exercising with their avatar. For social engagement, participants signed up to use the virtual world in groups of 3–4 participants but 75% of time in SL spent on independent activity rather than social interaction	Participants, $n = 92$, were recruited using mass email at a large Midwestern university & flyers in the local community (population = 115,000), who were overweight & seeking to lose weight healthily 98%, $n = 90$, were female; 2% ($n = 2$) male but did not complete the study & were dropped from analysis (total sample = 90 females) Age range 18–61 years (m = 25, SD = 9.92) Seventy (76%) identified as white, 12 (13%) as African American/ black, 9 (10%) as Asian, 4 (4%) as Hispanic/Latino, & 1 (1%) as other.	Self-efficacy & weight loss Measures were administered at week 1 (Time1) & week 4 (Time2). Midpoint (week 2) online survey emailed to participants to maintain engagement. (i) Exercise efficacy – measured using the abbreviated version of the Self-Efficacy & Exercise Habits Survey (Biocca, 1997). Participants rated their confidence to engage in exercise on a scale from 1 (I know I cannot) to 5 (I know I can) e.g. "Stick to your exercise program even when you have excessive demands at work." (ii) Nutrition efficacy - measured using the five item 5-a-day fruits & vegetables confidence scale from the abbreviated version of the Self-Efficacy & Healthy Eating Habits Scale, from 1 (not at all confident) to 5 (extremely confident) (Sallis, 2014) e.g. "Eat fruits & vegetables for a snack instead of unhealthy foods like chips or candy." (iii) frequency of exercise – measured by response to "In a typical week, how many days do you accumulate 30 min or more of purposeful physical activity per day?" (Sallis, 2014). (iv) 5-a-day eating behaviour (Time1) - self-report the number of servings of fruits & vegetables eaten on average/day. Response options ranged from 1 to 6+ servings. (v) Body Mass Index (BMI) - measured the participants' weight, height & BMI.	3D social virtual world - SL (using an avatar) - Avatar Fitness Club to practice exercising with their avatar. For social engagement, participants signed up to use the virtual world in groups of 3–4 participants.	Significant interaction effect between condition & time, $F(1, 38) = 4.93$, $p = 0.03$, $g2 = 0.11$ i.e. exercise efficacy increased for the SL group, but not for the control groups. The SL intervention, however, did not increase nutrition efficacy - $F(1, 38) = 1.99$, $p = 0.17$. Significant difference between experimental & control groups weight loss, $t(18) = 2.15$, $p = 0.04$. SL participants lost 1.75 pounds in comparison with 0.91 pounds for the control conditions - difference in weight-loss is small & is only cautiously optimistic for the use of SL in the relative short term for sustained weight loss. Self-presence was positively related to nutrition – $p < 0.05$., but not for exercise efficacy. Significant positive correlations between self-presence & avatar efficacy items $p < 0.01$. Research question 1: How do participants who are seeking to lose weight healthfully perceive the effectiveness of SL as a virtual tool? Coding analysis revealed two themes: virtual embodiment & health self-efficacy: (i) virtual embodiment theme was detected in participants' responses in relation to their feeling & perception of their avatar's effects on improving their motivation & body (ii) health self-efficacy responses focused on the ways that SL allowed them to try physical activities that they previously did not think they could do or had not done due to loss of motivation & efficacy. Research questions 2 analysis: What do participants who are seeking to lose weight healthfully perceive to be	28/48 58%

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Table 1 (*continued*)

Immersive Virtual Environments (IVE) Main findings Quality rating							
		(ii) no avatar virtual intervention control condition was added to investigate whether simply participating in some sort of virtual community might improve health self-efficacy & weight loss regardless of virtual embodiment Participants also spent most of their time independently exploring the site an average of two times/week. (iii) the no intervention control condition (i.e., no face-to-face & no virtual intervention) was included to test whether just being in the experiment impacted participants' health self-efficacy & weight loss.				the limitations of SL as a virtual tool? Three themes emerged: technology issues, time constraints & lack of enjoyment:- (i) Some participants expressed frustration due to technical difficulties. Generally, these responses were more characteristic of older (age 40+) participants in the study & were not widespread. In two cases, technical difficulties were cited as a stress that led to increased eating, which counteracted positive change. (ii) Time investment was an additional perceived drawback was. Some had difficulty finding time to use SL & others noted that they would rather spend the time exercising than being on the computer. There was a relationship between this theme & lack of enjoyment - Approximately 2/3 of participants who noted time constraints also noted a lack of enjoyment. (iii) Lack of enjoyment theme characterized the dislike some participants had for SL. These individuals stated that they generally did not enjoy video games. There was also a sense that they did not feel connected to their avatar. This lack of enjoyment prevented the participants from gaining the intended benefits.	
Cesa et al. (2013) Italy	RCT with one year follow up. (i) to evaluate the brief & long-term efficacy of the proposed approach (VR-enhanced CBT for obese inpatients with BED) in a randomized controlled trial. (ii) hypothesis - VR-enhanced CBT (ECT) is more effective than standard CBT & a control condition in: (1) maintaining & further improving weight loss, (2)	Random allocation to conditions: (i) Enhanced Cognitive Therapy (ECT) $n = 27$. During the standard inpatient program, participants received x 15 additional sessions over 5 weeks. After week 1, participants entered x 5 weekly group sessions similar to the CBT sessions (focused on concerns about body weight & shape & problematic eating) & x10 biweekly VR sessions. ECT treatment was based on a detailed protocol describing the contents of each of the 15 sessions. Manual based on the CBT approach described by	90 obese (BMI > 40) female patients with binge eating disorders (BED) referred to an obesity rehabilitation centre - 24 declined study participation before treatment commenced ($n = 66$). Criteria for participation: (i) Women aged 18–50 years (ii) who met DSM-IV-TR criteria for BED for at least 6 months prior to the beginning of the study, (iii) no other concurrent severe psychiatric disturbance (psychosis, depression with suicidal risk, alcohol or drug abuse), (iv) no concurrent involvement in other treatment for BED, including pharmacotherapy, (v) no concurrent medical condition not related to the disorder,	Outcome measures: weight, number of binge eating episodes during the previous month & body satisfaction. (i) BMI - Height was measured with a stadiometer & weight assessed with the participant in lightweight clothing with shoes removed, on a balance beam scale. (ii) binge eating - single question extracted from the EDI-Symptom Checklist was administered at each time-point to assess the number of binge eating episodes (with binge eating defined as the consumption of unusually large amounts of food with a subjective sense of loss of control during the last month).	NeuroVR open-source software used. This includes 14 virtual environments used by the therapist during a 60-min session with the patient. Prescribed VR environments. The environments present critical situations related to the maintaining/ relapse mechanisms (Home, Supermarket, Pub, Restaurant, Swimming Pool, Beach, Gymnasium) & two body image comparison areas. Through the VR experience, patients practiced both eating/ emotional/relational management & general	End of 6 week IP period ($n = 66$). Weight significantly decreased in all the three conditions (ECT: −6.17 kg, CI -7 to −5.3, $p < 0.001$; CBT: −7.1 kg, CI -7.9 to −6.2, $p < 0.001$; IP: −6.6 kg, CI -8.1 to −5.2, $p < 0.001$) at end of treatment (6 weeks); no significant differences between groups. Body satisfaction (BSS & CDRS) significantly improved in all groups with no difference across them. Body image concerns (BIAQ-Total) significantly improved only in the ECT condition.	37/42 88%

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Table 1 (*continued*)

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	maintaining binge eating remission at 1-year follow-up after discharge from a multimodal medically managed inpatient program (IP). (iii) ECT is more effective than standard CBT & a control condition in improving & maintaining body satisfaction.	Fairburn and Wilson (1993) & Ricca et al. (2000) piloted & adapted to an inpatient setting. (ii) Cognitive Behavioural Therapy (CBT) $n = 20$: during the standard inpatient program, participants received x 15 additional cognitive behaviour therapy (CBT) sessions over 5 weeks. Therapists followed a detailed manual that outlined the contents of each session. (iii) Control: Standard care - inpatient multimodal treatment (IP) $n = 19$: consisted of hospital-based living for a duration of 6 weeks. Inpatients received medical, nutritional, physical & psychological care. Participants maintained a low-calorie diet (tailored to patients' needs), entered weekly nutritional groups held by dieticians, received psychological support both in individual & group settings & undertook physical training.	(vi) written & informed consent to participate.	(iii) body image/satisfaction – (a) The Italian version of the Body Satisfaction Scale (BSS) (b) The Italian version of the Body Image Avoidance Questionnaire (BIAQ) (c) Contour Drawing Rating Scale (CDRS)	decision-making & problem-solving skills. By directly practicing these skills within the VR environment, patients were helped in developing specific strategies for avoiding &/or coping with triggering situations. The first session was used to assess any stimuli that could elicit abnormal eating behaviour. Specifically, the attention was focused on a patient's concerns about food, eating, shape, & weight. The next 14 sessions were used to assess & modify: (i) Expectations & Emotions Related to Food & Weight (Functional Analysis) (ii) Strategies Used to Cope With Difficult Interpersonal & Potential Maintenance Situations (iii) Body Experience of the Subject	1 year follow-up ($n = 44$). Both ECT & BCT maintaining or furthering were effective at maintaining or furthering weight loss at 1-year follow-up (p = 0.52 both compared to IP). No significant difference CBT & ECT. Control participants regained on average most of the weight they had lost during the inpatient program. Binge eating episodes decreased to zero during the inpatient program but were reported again in all the three groups at 1-year follow-up. No significant difference between groups. .	
Johnston et al. (2012) USA	Controlled before & after study. To explore the effectiveness of a virtual-world weight loss program relative to weight loss, behaviour change & self-efficacy.	Club One Island's virtual-world program compared with a face-to-face program similar in structure & content offered in a commercial fitness club setting. Virtual-world program: An interactive weight loss community. Provides participants with a professional team, education & specialized tools to help them overcome individual barriers to weight loss. Access to educational components & specialized tools is available 24 h a day, 7 days a week, along with virtual world & email access to instructors.	Intervention: x38 participants recruited via print & online media. Participants were aged 18+ years, with a BMI of 25 kg/m2 or greater & had access to an Internet-connected computer. 76% female (25/33), mean age = 46.3 (SD 9.6) years; 73% (24/33) held college or advanced degrees & 76% (25/33) had annual incomes exceeding US $75,000. All 33 (5 lost to follow up) reported they were novice users of SL (0–3 months) Control (face-to-face group): x24 participants	Primary Outcomes: Height, weight & BMI - recorded using standard techniques at baseline (pre-program) & within 1 week of program completion. Percentage change in baseline weight was calculated; a reduction of 5% or more of baseline weight results in clinically significant health benefits. Baseline & post surveys captured data regarding health-related behaviours (i.e. general health, sleep & degree of moderate & vigorous physical activity) & nutrition & eating habits (i.e.	Club One Island – designed to: (i) provide an environment that closely mirrors the physical world; (ii) be visually & functionally engaging; offers interactive 3D spaces (e.g. a restaurant, Mini-Mart convenience store & an encouragement room), creative educational tools (e.g. a nutritional jeopardy game & a fire pit illustrating how the body uses food as fuel), over 30 movement activities (e.g. bikes & bike paths, surfing, exercise balls, lap swim, basketball, weight lifting, yoga, dancing & rock	At baseline, virtual-world participants reported a statistically significant (p = 0.03) higher negative attitude towards exercising at a real club (mean score 3.35, SD 1.13, on a scale of 1 to 7, where 1 = strongly disagree; higher scores represent more negative attitudes) than face-to-face participants (2.69, SD 0.97). Primary Outcomes: No significant baseline differences were noted between groups for weight, BMI, general health, fruit & vegetable consumption, breakfast frequency & physical activity self-efficacy. Significant baseline differences were observed for moderate physical activity (p = 0.02), vigorous physical	24/42 57%

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Table 1 (*continued*)

Immersive Virtual Environments (IVE)
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		Prior to the start of the virtual-world program, participants received technical training & support (e.g. computer setup & navigating the island). 12-week program delivered to cohorts of 15–20 participants for a total of 48 instructor hours. Each week, four 1-h classes (Nutrition, Movement, Healthy Habits & Support Group) are led by certified fitness, nutrition & support professionals. Each week addresses a common theme (e.g. emotion as related to eating) across all 4 classes. Face-to Face program: Comparison face-to-face group had to attend a real facility. The program included instructor-led weekly educational sessions on nutrition, movement & habit change, as well as a social support group meeting. Program participants were also able to use club equipment & facilities during normal business hours	were recruited, convenience sample, via email & newsletters from Club One's member base. Enrollees were of a similar age & BMI 95% (20/21) female, mean age = 37.5 (SD 10.6) years; 90% (19/21) held college or advanced degrees & 71% (15/21) reported incomes over US $75,000	frequency of breakfast & number of servings of fruit & vegetables/day - adapted from the US Centers for Disease Control & Prevention's Behavioural Risk Factor Surveillance System Survey). Secondary Outcomes: Self-efficacy, with regard to both physical activity & weight management were measured using the Physical Activity Confidence Scale & the Weight Efficacy Lifestyle Questionnaire (WEL). Attitudes towards exercising at a health club were captured with items adapted from Miller and Miller (2010) in pre-survey Virtual-world participants were asked about prior experience with SL (post survey)	climbing) & numerous healthy habits tools (e.g. tracking charts). All elements are intended to engage participants in social networking, play & learning. Through setting up learning situations that incorporate practicing new behaviours (eg, throwing away 3D food, addressing the "food pushers" & non- supportive people in their lives & doing any physical activity in public), Club One Island is intended to help participants overcome their fears related to weight loss. The weight loss program was designed to move participants from a diet & exercise cycle of weight loss & gain to a view that they are on a healthy life path that does not have a stop & end date, but is maintainable for the rest of their lives Participants choose how their avatar looks (actual or desired) & are able to make modifications over time, as wanted. The Nutrition, Movement & Healthy Habits classes were all designed in such a way that participants were always moving.	activity ($p = 0.001$), sleep ($p = 0.02$) & WEL ($p = 0.04$) in favour of F2F group who were existing fitness club members. No significant group x time interactions were found. Both groups lost a significant amount of weight at 12 weeks (virtual world: 3.9 kg, $P < 0.001$; face-to-face: 2.8 kg, $p = 0\ 0.002$). Compared with baseline, the virtual-world group lost an average of 4.3% (range − 17.3% to 3.3%), with 33% (11/33) of the participants losing a clinically significant (≥5%) amount of weight. Face-to-face group lost an average of 3.0% (range − 11.0% to 2.7%), with 29% (6/21) losing a clinically significant (≥5%) amount. 15.2% (5/33) of the virtual-world & 14.3% (3/21) of the face-to-face groups lost 7% or more of their body weight. No significant differences were seen between groups for the percentage of weight lost ($p = 0.34$) or the percentage of participants losing 5% or more of their baseline body weight ($p = 0.39$). Secondary Outcomes: The group × time interaction was significant for pre- to post intervention general health ($p = 0.01$), moderate & vigorous physical Activity ($p = 0.04$), physical activity self-efficacy ($p = 0.02$), fruit & vegetable consumption ($p < 0.001$) & WEL ($p < 0.001$) for the virtual-world group. Significant improvements across all of the variables were seen for the virtual-world group; the face-to-face group had non-significant improvements in self-

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Table 1 (*continued*)

Immersive Virtual Environments (IVE) Main findings Quality rating							
						efficacy for physical activity & WEL, as well as for fruit & vegetable consumption. Virtual-world participants reported a statistically significant (p = 0.03) higher negative attitude towards exercising at a real club, (mean score 3.35, SD 1.13, on a scale of 1 to 7, where 1 = strongly disagree; higher scores represent more negative attitudes) than face-to-face participants (2.69, SD 0.97). Face-to-face group reported decreases in moderate & vigorous physical activity that were nonsignificant. A significant time effect for general health & breakfast consumption was noted in both groups. Significant improvement in perceptions of general health ($p < 0.001$) & an increase in the number of days the virtual-world group ate breakfast ($p = 0.003$) noted. No significant change in these variables for the face-to-face group. Virtual-world participants created avatars that reflected real depictions of themselves – as they lost weight in the real world, changes were made to their avatar's appearance to reflect this.	
Manzoni et al. (2016) Italy	RCT with one year follow up. (i) to evaluate brief & long-term incremental efficacy of the VR-enhanced CBT of obesity in a randomized controlled trial with morbid BMI > 40) female obese patients referred to an inpatient behavioural program. (ii) hypothesis that the VR-enhanced CBT is more	Random allocation to groups: (i) VR $n = 46$. After week 1, participants entered x 5 weekly group sessions similar to the CBT sessions (focused on concerns about body weight & shape & problematic eating) & x10 biweekly VR sessions using NeuroVR open source software (includes 14 virtual environments presenting critical situations related to the maintaining/ relapse	$n = 163$ women BMI > 40, 18–50 years of age; no other concurrent severe eating disorder. 50 participants lost to follow-up leaving sample of 113 in analysis No males admitted during data collection period met inclusion criteria of BMI > 40	Primary outcome measure was weight-loss maintenance. BMI - Height measured with a stadiometer; weight was assessed on a balance beam scale with the participant in lightweight clothing with shoes removed. Binge eating & body image/ satisfaction: • The Italian version of the Body Satisfaction Scale BSS.4 • The Italian version45 of the Body Image Avoidance	Virtual reality (VR)-enhanced CBT. NeuroVR open source software was used for the VR sessions – Through the VR experience, patients practice both eating/emotional/ relational management & general decision-making & problem-solving skills. By directly practicing these skills within the VR environment, patients are helped in developing specific strategies	Out of 163 patients recruited, 113 responded to the follow-up call & provided their weight data. The majority of patients who did not respond were in the SBP group ($n = 21$), followed by CBT ($n = 14$) & VR ($n = 10$). The chi-square test showed a significant association between the dropout rates & the experimental conditions ($p = 0.02$) with fewer patients being lost from VR or CBT treatments. All measures improved significantly at discharge from the inpatient program from baseline & no significant	37/42 88%

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Table 1 (*continued*)

Immersive Virtual Environments (IVE) Main findings Quality rating						
	effective than the inpatient program only as well as standard CBT in maintaining or further improving weight loss at 1 year follow-up.	mechanisms (home, supermarket, pub, restaurant, swimming pool, beach, gymnasium) & two body-image comparison areas. Environments used by therapist during a x60 minute session with the patient. (ii) Cognitive Behavioural Therapy (CBT) *n* = 38: After week 1, patients entered x5 weekly group sessions aimed at addressing weight & primary goals & x 10 biweekly individual sessions, aimed at establishing & maintaining weight loss, addressing barriers to weight loss, increasing activity, addressing body image concerns & supporting weight maintenance. during the standard inpatient program. Therapists followed a detailed manual based on the CBT approach (Cooper et al., 2003, 2010) & adapted to an inpatient setting. Patients were taught to self-monitor their food intake & eating patterns thoughts, as well as the circumstances & environment surrounding eating (e.g. whether eating alone or with others, speed of eating, & place of eating). Patients were also taught to identify problems in eating, mood & thinking patterns & to develop alternative patterns gradually. (iii) Standard behavioural program (SBP) *n* = 29 - hospital-based living for 6 weeks. Inpatients receive medical, nutritional, physical & psychological care the goal of which is to provide practical guidelines (e.g. stressing gradual weight loss		Questionnaire - BIAQ • The Contour Drawing Rating Scale - CDRS	for avoiding &/or coping with triggering situations.	difference was found between. One-way ANCOVA on the post IP period to follow-up weight changes showed a significant group effect. Post hoc analyses revealed a significant difference between the VR & the SBP conditions & also between the CBT & the SBP conditions, but not between VR & CBT. Odds ratios showed that patients in the VR condition had a greater probability of maintaining or improving weight loss at 1 year follow-up than SBP patients (48% vs. 11%, $p = 0.004$) & to a lesser extent, than CBT patients had (48% vs. 29%, $p = 0.08$). Only the VR-enhanced CBT was effective in improving weight loss at 1 year follow-up. Participants who received only the inpatient program regained back, on average, most of the weight they had lost. The CBT group showed a non-significant weight increase, while no change was found within the VR group. Findings support the hypothesis that a VR module addressing the locked negative memory of the body may enhance the long-term efficacy of standard CBT.

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Table 1 (*continued*)

Immersive Virtual Environments (IVE) Main findings Quality rating							
		with the caloric restriction achieved largely by reductions in fat intake), plus a low-calorie diet (1200 kcal/day) & physical training (x30 minutes of walking twice a week as a minimum).					
Napolitano et al. (2013) USA	Mixed methods study: (i) an online survey to obtain feedback about an avatar program for modelling weight loss behaviours. ii) technology development & usability testing.	Phase 2: 4-week usability test using four virtual environments - supermarket, home gym, dining room/kitchen & living room, in which the avatar demonstrated healthy weight control behaviours related to weekly session topics in traditional behavioural weight control programs including: (i) navigating a supermarket & shopping for low calorie items (ii) physical activity, (iii) portion sizes & (iv) stimulus control 4× weekly 30 min sessions including standardized information sharing through leaflets & videos, opportunity to ask questions & weigh in. Diet diaries were reviewed to determine adequate calorie intake recommended by BMI & also activity goal engagement. No specific weight loss target not given but general goal of 1–2 lbs. per week vocalised. Participant chose avatar appearance which did not change shape over time. Session content was delivered prior to avatar modelling electronically via a standardized digital recording by a registered dietitian (topics presented as they would be in face-to-face treatment)	Phase 1: $n = 128$ females were recruited online via postings, as well as in-person announcements & flyer postings (online recruitment was not limited regionally). Mean age = 34.10 years (SD = 13.01 years, range = 18–60 years); race = 57.0% white; 25.8% black; 10.2% Asian/Pacific Islander; 3.9% Hispanic/Latino; 3.1% other. Mean BMI = 34.30 kg/m2, (SD = 8.15 kg/m2). Participants were overweight/obese (declared height & weight resulting in BMI ≥ 25) & interested in losing weight Phase 2: $n = 8$. Inclusion 18-65 yrs., BMI 25–40, no concurrent weight loss treatment, no health contraindications. Mean age = 44.13 years (SD = 10.56). Mean weight = 93.8 kg (SD = 16.18); Mean BMI = 33.32, (SD = 3.45); Race: 62.5% black, 25% Caucasian, 12.5% Hispanic. Participants reported accessing the Internet/email at least daily & enjoyed using technology. None had previous experience of using avatar-based technology.	Phase 1 measures: Demographics - Age, race, self-reported height & weight (BMI) & dieting history over last year (e.g. "In the past year, how many times have you started a weight loss program on your own that lasted for 3 days or less?"). Technology Use: Participants provided information related to their computer & video game use (e.g. "Do you play (or have you played) online role-playing games that use avatars (e.g. World of Warcraft, The Sims)?") & exposure to or interest in technology & VR (e.g. "How much do you enjoy using technology (for example, Internet, computer, cell phone, Kindle)?" & "Have you ever used VR?"). Program Interest: Participants provided information about their interest in a VR weight loss program, perceptions of perceived helpfulness, suggestions for duration of sessions & skills they would like to see modelled. Phase 2 measures: (i) Height & Weight: height taken using a stadiometer to the nearest one-fourth inch. Body weight was measured on a calibrated scale; BMI calculated based on height & weight [BMI = weight (kg) / height2 (m2)]. (ii) Physical Activity Self-Efficacy: The five-item physical	Phase 2: Programming developed in-house using a SL platform. Avatars varied in shape & size based on figure rating scales (Thompson and Gray, 1995; Stunkard et al., 1983) & were available in three skin tones based on feedback received during phase 1. The avatar body shapes were customised to reflect dimensions of obesity by customising the various body parts from a standard shape present in the inventory section of the SL platform. Four virtual environments were created - supermarket, home gym, dining room/kitchen & living room, in which the avatar demonstrated healthy weight control behaviours related to weekly session topics	Phase 1 findings Dieting History: More than two-thirds (71.9%) of participants had attempted to lose weight during the past year, with the average number of attempts lasting up to 3 days = 4 (SD = 8.60). Women reported most commonly using their own diet (46.1%) & exercise (37.5%) plans. Technology Use: All participants accessed the internet/email at least daily & 90.6% enjoyed using technology most or all of the time; 32.0% played online games that used avatars. The majority of participants had never used VR (95.3%) or SL (98.4%). Program Interest: Interest in an avatar-based program for modelling weight loss skills was high: 88.3% of participants reported they would participate in a program that used an avatar to help practice weight loss skills. Qualitative responses included: "Seeing 'myself' exercising or eating correctly… will help me visualize myself following these examples," & "I would use the avatar because simulating a behaviour can help reinforce positive choices." A majority of participants (71.9%) believed such a program would be at least somewhat helpful & anticipated that the avatar-based program would yield strong effects [anticipated average weight loss of 3.4 kg (SD = 1.97 kg;	34/42 81%

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Table 1 (*continued*)

Immersive Virtual Environments (IVE) Main findings Quality rating		
	activity self-efficacy (Marcus et al., 1992) to assess confidence to exercise in challenging situations (e.g. “when I am tired”) using a five-point Likert scale (“not at all” to “extremely confident”) (internal consistency = 0.76 & 1-week test–retest reliability = 0.90). (iii) Weight Self-Efficacy: measured using Clark et al. (1991) self-efficacy in weight management scale to measure perceived control over food-related behaviours. (iv) Goal Setting & Planning: measured using goal setting & the exercise goal-setting scale & the exercise, planning & scheduling scale (Rovniak et al., 2002). Same measure adapted to assess goal setting & planning for nutrition & weight loss. Measure has good internal consistency (exercise goal-setting scale = 0.89; exercise planning & scheduling scale = 0.87) (Rovniak et al., 2002). Consumer Satisfaction: Participants completed weekly exit interviews & a post-treatment survey that assessed the degree to which the program & its components (e.g. virtual avatar modelling, video content, handouts) were helpful. User satisfaction & preference components of usability: Participants completed weekly exit interviews & a post-treatment survey that assessed the degree of user satisfaction & preference components of usability e.g. “How interested would you be in having the avatar, or virtual model, look exactly like you?”	range = 0.91–13.61 kg) during the first month of a VR program & 7.92 kg (SD = 3.88 kg; range = 1.36–27.22 kg) after 3 months]. Phase 2: Most women (87.5%) stated that the virtual models were helpful. Average weight loss after 4 weeks was 1.6 kg (SD = 1.7). Increased confidence on physical activity self-efficacy scale (p = 0.01). Usability: 100% reported they would recommend the program to others and felt it influenced their diet/exercise behaviour. 87.5% found avatar models helpful. User Preference: 25% did not want an avatar to reflect self but 75% were interest in an avatar that changed size & shape as they progressed through the program.

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Table 1 (*continued*)

Immersive Virtual Environments (IVE) Main findings Quality rating							
Ossolinski et al. (2017) Australia	RCT To evaluate the effect of (i) a personalised future self-image (photograph) on weight change over a 6-month period & (ii) to include both men & women of any age over 18 years.	Participants randomized to receive a current & future self-image (photographic still based image of self at one of 5 future time points: 4, 8, 12, 26 or 52 weeks based on personal choice) immediately (early intervention group) or after 8 weeks (delayed intervention). At recruitment, participants complete a questionnaire outlining demographic details & an assessment of motivational state using the Prochaska Transtheoretical Model of Behaviour Change. Baseline height, weight & waist circumference were measured for all participants. All participants received 15 mins general lifestyle advice for weight loss & resource pamphlet listing freely available online resources for weight managements & accredited professional & weight loss programmes. Weight loss methods chosen by the individual. Participants asked to return every 4 weeks for 24 weeks to record weight on original calibrated scales. Researcher provided information on sources of advice at weigh-ins but not intervening periods. Participants randomized again at 16 week visit to receive either 2nd picture of choice of future self, based on new parameters or continue with original image.	A sample size of 150 was determined to have the power to detect a 1-kg weight difference between groups (based mean weight difference seen at 8 weeks in the pilot study (Jiwa et al., 2015) A total of 145 participants were recruited over an 8 month period. Male & female; aged 18 years +; BMI $>$ 25; wanting to lose weight. Study engagement assumed if participant returned for 1st weigh in 4 weeks after recruitment. Study completers were those who returned to be weighed at week 20 or 24. For missing data, linear interpolation was undertaken & straight line applied between missing values. No 4 week weigh in = non-starters. Stopped returning for weigh in before week 20 = drop out, but included in intention to treat analysis.	Primary outcome: Weight loss over 16 weeks - using participants whose weights were measured at weeks 8 &16 (at least). Secondary outcomes: Weight loss & change in waist circumference over 24 weeks - undertaken using only 'completers' who attended at weeks 8 &16.	A computerised application (app) prototype called 'Future Me' developed by the research team. The app portrays the effect of lifestyle on future personal appearance using input calorie & exercise information to predict future BMI.	At 24 weeks significant change in weight overall ($p < 0.0001$) & a difference in rate of change between groups (delayed-image group: −0.60%, early-image group: −0.42%, $p = 0.01$). Men lost weight at a greater rate than women. Participants in delayed image group lost more weight than immediate image group. No significant difference in change in waist circumference or proportion that lost 5% body weight between early/late image groups although the latter was greatest in delayed image group (may reflect greater proportion of participants in 'contemplation' on state of change scale).	33/42 78.6%

Table 2
Weight loss.

Cesa et al. (2013)	Clinical significant weight loss • Both routine and avatar arm achieved clinical significant weight loss in 5/6 weeks (routine arm = 5.9%, avatar arm = 6.0%). • Only avatar participants maintained or increased this weight loss at 12 month follow up compared to baseline measures (routine 2.1%, avatar 6.8%). • Routine participants regained an average of 2.4kgs of weight from end of programme up to 12 months. Weight loss • Significant decreases in weight in all three arms of their RCT at 6 weeks among women with binge eating disorder (BED): (i) Enhanced Cognitive Therapy (ECT) -6.17 kg, CI -7 to −5.3, $p < 0.001$; (ii) Cognitive Behavioural Therapy (CBT) -7.1 kg, CI -7.9 to −6.2, $p < 0.001$ and (iii) Standard care, inpatient multimodal treatment (IP) -6.6 kg, CI -8.1 to −5.2, $p < 0.001$). • No significant differences reported between the groups at the end of the 6 week treatment • Statistically significant increases in weight and BMI were observed in the IP treatment group (from 105 kg to 109.3 kg; $P < 0.001$) at one year follow-up; • No statistically significant weight and BMI changes were found between the end of the inpatient treatment and 1-year follow-up in CBT and ECT groups. Only ECT was effective for further improving weight loss at 1-year follow-up ($p < 0.031$).
Manzoni et al. (2016)	Clinical significant weight loss • Both routine and avatar arm achieved clinical significant weight loss at 5/6 weeks (routine 6.2%, avatar 6.25%). • Only avatar arm participants maintained or increased 5% weight loss at 12 months (avatar = 5.98%). • The routine arm participants increased weight relative to initial weight value (increase weight of 4.7 kg or 4.27%). This difference is clinically and statistically significant. Weight loss • Significant differences between the VR enhanced CBT and the standard behavioural program (SBP) conditions, and also between the CBT and the SBP conditions, but not between VR and CBT in their inpatient programme for women with morbid obesity. • Odds ratios showed that patients in the VR enhanced CBT condition had a greater probability of maintaining or improving weight loss at 1 year follow-up than SBP patients (48% vs. 11%, $p = 0.004$) and CBT alone (48% vs. 29%, $p = 0.08$). Only the VR-enhanced CBT was effective in improving weight loss at 1 year follow-up. • Participants who received only the inpatient program regained back, on average, most of the weight they had lost. The CBT group showed a nonsignificant weight increase, but no change was found within the VR-enhanced CBT group.
Johnston et al. (2012)	Clinical significant weight loss • Neither routine nor avatar arm lost 5% weight in the 12 week programme. However, participants in the avatar arm lost a greater weight proportion (avatar 4.3%, routine 3.0%), but this was not statistically significant. Weight loss • Significant weight loss in the virtual world group - 3.9 kg, $p < 0$ 0.001 and control face-to-face group - 2.8 kg, $p = 0$ 0.002). • Compared with baseline, the virtual-world group lost an average of 4.3% (range − 17.3% to 3.3%), with 33% (11/33) of the participants losing a clinically significant (≥5%) amount of weight. • Face-to-face group lost an average of 3.0% (range − 11.0% to 2.7%); with 29% (6/21) losing a clinically significant amount. 15.2% (5/33) of the virtual-world and 14.3% (3/21) of the face-to-face groups lost 7% or more of their body weight. There was no significant difference between groups in the percentage of weight lost ($p = 0.34$) or the percentage of participants losing 5% or more of their baseline body weight ($p = 0.39$).
Behm-Morawitz et al. (2016)	• Due to differences in study design and reporting, it was not possible to discuss differences between routine and avatar for this study. • Significant difference in weight loss between experimental and control groups, $t(18) = 2.15$, $p = 0.04$, at the end of a 4 week programme with overweight adults seeking to lose weight healthily. • The difference in weight loss overall was small with Second Life participants losing 1.75 pounds in comparison to 0.91 pounds for the control conditions.
Napolitano et al. (2013) (no control group)	• Due to differences in study design and reporting, it was not possible to discuss differences between routine and avatar for this study. • Average weight loss of 1.6 kg (SD = 1.7) in overweight women after 4 weeks
Ossolinski et al. (2017)	• Due to differences in study design and reporting, it was not possible to discuss differences between routine and avatar for this study. • Significant changes in overall weight ($p < 0.0001$) at 24 weeks of the personalised future self-image weight loss programme and a significant difference in the rate of change between groups: delayed-image group −0.60 kg, early-image group −0.42 kg, $p = 0.01$). Men lost more weight than women. Participants in the delayed image group lost more weight than immediate image group.

2013). The lower quality percentage scores were generally attributable to poor reporting of research design and the findings being unclear, poorly described or inconsistently reported. Three studies were conducted in the USA (Behm-Morawitz et al., 2016; Napolitano et al., 2013; Johnston et al., 2012), two in Italy (Manzoni et al., 2016; Cesa et al., 2013) and one in Australia (Ossolinski et al., 2017).

3.2. Types of interventions

Four papers reported Randomized Controlled Trials (RCTs) (Ossolinski et al., 2017; Behm-Morawitz et al., 2016; Manzoni et al., 2016; Cesa et al., 2013), one study used a mixed methods approach (Napolitano et al., 2013) and one study used a before-after research design (Johnston et al., 2012). The target participant group varied across the studies with weight loss intervention aimed at: (a) obese women with binge eating disorders (Cesa et al., 2013); (b) women with morbid obesity (Manzoni et al., 2016); (c) overweight adults (Behm-Morawitz et al., 2016; Napolitano et al., 2013); (d) adults with a BMI of $25Kg/m^2$ or greater with access to an internet-connected computer (Johnston et al., 2012) and (e) adults with a BMI > $25Kg/m^2$ wanting to lose weight (Ossolinski et al., 2017).

3.3. Intervention delivery

Four papers used avatars within a 3D social virtual world environment (second life or similar) (Behm-Morawitz et al., 2016; Cesa et al., 2013; Johnston et al., 2012; Manzoni et al., 2016). One paper used a tailored avatar within a non-immersive VR environment (Napolitano et al., 2013) and another used a personalised computerised avatar application (app) (Ossolinski et al., 2017).

3.4. Weight loss

Of the six included papers, evaluation of weight loss between routine and routine plus avatar intervention was possible in three (Manzoni et al., 2016; Cesa et al., 2013; Johnston et al., 2012). A summary of these is provided in Table 2. The remaining 3 papers all identified weight loss in the intervention group, but diverse designs prevented direct comparison.

3.5. Avatar personalisation

Two papers reported using some form of avatar personalisation (Ossolinski et al., 2017; Napolitano et al., 2013). Napolitano et al. (2013) described a futures tailored avatar and while reported average weight loss after the 4-week programme was not clinically significant (< 5% weight loss), most women (87.5%) stated that the virtual model within the avatar programme was helpful. In contrast, Ossolinski et al. (2017) used a personalised app incorporating participant self-images in the creation of an avatar. Unfortunately, Ossolinski et al. (2017) did not use a routine arm for comparison, but instead adopted an immediate and delayed (8 weeks post weight loss programme commencement) avatar intervention approach with images of current and future selves. Findings suggested that delaying access to personalised avatar future images promoted greater weight loss, potentially due to increasing longevity of participant engagement and personal contemplation on stage of change (Prochaska et al., 1997).

3.6. Exercise and physical activity self-efficacy

Three papers reported exercise/physical activity efficacy and frequency as a process outcome (Behm-Morawitz et al., 2016; Napolitano et al., 2013; Johnston et al., 2012). Behm-Morawitz et al. (2016) found a significant interaction effect between condition and time [$F(1, 38) = 4.93$, $p = 0.03$] whereby exercise efficacy increased for the Second Life (avatar) group, but not for the control group. Similarly, Johnston et al. (2012) found a significant in group × time interaction for pre-to-post intervention for moderate and vigorous physical activity and physical activity self-efficacy among the virtual world (avatar) group compared to the face-to-face intervention group. However, this difference is contradicted by the statistically significant ($p = 0.03$) greater negative attitude (mean score 3.35, SD 1.13, on a scale of 1 to 7, where 1 = strongly disagree; higher scores represent more negative attitudes) towards exercising at a real club compared to their routine arm counterparts (2.69, SD 0.97). Napolitano et al. (2013) also reported increased confidence on the physical activity self-efficacy scale ($p = 0.01$) within their 4-week weight management programme using four virtual environments. However, no routine comparison arm was available.

3.7. Eating behaviour/nutrition efficacy

Two papers reported eating behaviour and nutrition efficacy as a process outcome (Behm-Morawitz et al., 2016; Johnston et al., 2012). Behm-Morawitz et al. (2016) reported no statistically significant interaction between condition and time [$F(1, 38) = 1.99$, $p = 0.17$] for nutrition efficacy in either the Second Life (avatar) intervention or control group. In contrast, Johnston et al. (2012) found significant in group × time interaction for pre-to-post intervention fruit and vegetable consumption ($p = 0.007$) in the virtual-world group. They also found a statistically significant improvement in perceptions of general health ($p < 0.001$) and an increase in the number of days the virtual-world (avatar) group ate breakfast ($p = 0.003$) compared to the face-to-face routine intervention group.

3.8. Body image & body satisfaction

Two papers reported body image and body satisfaction as a process outcome measure. Cesa et al. (2013) found that body satisfaction significantly improved in all groups, but body image concerns only reduced significantly in the virtual reality-enhanced cognitive behaviour therapy group ($p = 0.031$). In contrast, Manzoni et al. (2016) found that all measures for body image and body satisfaction improved significantly at discharge from the intervention program with no significant difference was found between groups.

3.9. Weight management self-efficacy

Only one paper (Johnston et al., 2012) reported weight management self-efficacy as a process outcome. They found significant increases ($p < 0.001$) in group × time interaction for pre-to-post intervention using the Weight Efficacy Lifestyle (WEL) Questionnaire (Clark et al., 1991).

3.10. Self-presence & avatar efficacy

Only one paper reported self-presence and avatar efficacy (Behm-Morawitz et al., 2016). In this study significant positive correlations between self-presence and avatar efficacy items ($p < 0.01$) were found.

3.11. Avatar acceptability and usage

Only one paper reported avatar acceptability and usage as a secondary outcome measure (Napolitano et al., 2013). Napolitano et al. (2013) found that interest in an avatar-based program for modelling weight loss skills in women was high with 88.3% of participants reporting that they would participate in such a program to help practice weight loss skills. 71.9% of participants also believed that an avatar-based program would be at least somewhat helpful as part of a weight loss programme and anticipated that the avatar-based program would yield strong effects in terms of weight loss. 87.5% of participants indicated that the virtual models were helpful and all reported the avatar-based programme influenced both their diet and exercise behaviour.

4. Discussion

The evidence presented in this systematic review suggests that the inclusion of avatar technology within weight loss interventions leads to greater weight loss and weight maintenance compared to routine interventions, although the differences were no consistent in terms of statistical or clinical significance (Ossolinski et al., 2017; Behm-Morawitz et al., 2016; Manzoni et al., 2016; Cesa et al., 2013). Avatar personalisation may provide some additional benefits by engaging and retaining interest and motivation to comply with a defined weight loss programme although the data to support this is less robust (Ossolinski et al., 2017; Napolitano et al., 2013).

While the quality of the included studies was moderate to high overall, the heterogeneous nature of the avatar interventions, content and delivery of weight loss programmes, study time frames and participant demographics meant that direct comparison of results was impossible. That said, the evidence suggests that participants who are able to access avatar representations do engage more with the weight loss programme (Manzoni et al., 2016; Napolitano et al., 2013; Johnston et al., 2012) are more likely to achieve weight loss outcomes (Behm-Morawitz et al., 2016; Johnston et al., 2012) and significantly more likely to maintain weight loss beyond the end point of the weight loss programme (Manzoni et al., 2016; Cesa et al., 2013). Of additional interest is the finding that participants creating their own avatars in Second Life created avatars that closely depicted themselves, or were interested in avatars that reflected self, suggesting that personalisation of the virtual self is an important aspect of avatar engagement (Behm-Morawitz et al., 2016; Napolitano et al., 2013). However, this needs further exploration to understand the implications of self-identification in the virtual world and how this might be best utilised to achieve behaviour modification and ultimately improvements in weight loss and wider health outcomes.

It was interesting to note that while avatar experience increased exercise self-efficacy (i.e. the belief that one could undertake moderate to vigorous physical activity), this did not translate into an appetite for real world exercise activity and appeared to reduce the likelihood of attending a gym environment where such activity could be undertaken (Johnston et al., 2012) suggesting an apparent contradiction. The reasons behind this are uncertain and not discussed directly by the authors and are therefore worthy of further exploration to understand the potential negative consequences of avatar engagement. While exercise efficacy increased through engagement in the virtual world, this did not translate into an appetite for real world exercise activity, although the reasons behind this are uncertain. It is possible that this is related to increasing body self-consciousness as a consequence of avatar engagement although evidence from Manzoni et al. (2016) and Cesa et al. (2013) would contradict this perspective, therefore creating uncertainty over underlying causal factors.

Several evidence based weight loss strategies have traditionally been employed: diet-plus-exercise, diet-only (Wu et al., 2009); behaviour-based weight loss interventions and pharmacotherapy-based weight loss interventions (Curry et al., 2018). Diet and exercise programs have been found to be more effective than diet only programs or exercise only programs (Wu et al., 2009). Likewise, behaviour-based weight loss interventions, with or without weight loss medications, were associated with greater weight loss achievement (LeBlanc et al., 2018). However, motivation is still required to adhere to weight loss behaviours for both initial and long term weight loss to be realised (Teixeira et al., 2012).

Attrition and non-adherence is a common problem across all weight loss interventions with reported mean attrition rates ranging from 10% to over 80% (LeBlanc et al., 2018; Dombrowski et al., 2014; Moroshko et al., 2011; Franz et al., 2007). Within the studies included in this review, reasonable recruitment and attrition rates were achieved, particularly within the intervention arms. This suggests a general interest and acceptability of avatar technologies as a tool to weight loss. However, of importance is the lack of male participants across the reported intervention studies included in this review. This is consistent with another review that found fewer men joined mixed-sex weight loss interventions than women, but where they did, more completed the programmes and tended to show a greater percentage weight loss than women (Robertson et al., 2014). The lack of male participants may also reflect the greater societal pressure experienced by females to conform to expected body shapes and sizes as reiterated through advertisement and marketing materials or a lack of awareness among males of their weight condition as the societal 'norm' of what is obese has increased globally. While we have suggested possible reasons for this finding, the reasons behind the recruitment gender polarisation remains unclear and worthy of further exploration a tailoring of weight loss interventions for delivery to men could to promote greater engagement (Robertson et al., 2014).

While the evidence above has been reported faithfully and clearly supports the further development of avatar technologies within weight loss interventions, the limited volume of studies and their heterogeneous nature means that the findings should be interpreted with caution. Further work is required to understand the impact and implication of avatar technologies on weight loss and wider health care outcomes.

4.1. Limitations

The searches were limited to English language and included papers which were published in peer reviewed journals. No conference abstracts or grey literature pertinent to the review question were identified. In addition to the small number of included papers, the wide variability in the design and quality of the studies limits the conclusions that can be made. There is a need for more well-designed studies comparing avatar and personalised avatar interventions. Randomized controlled trials and double-blind experiments with adequately powered sample sizes, control groups and long-term follow-up assessments of outcomes are required to tease out the effects of personalisation on mediators like motivation, self-efficacy, health and wellbeing and user experience. The studies included in this review often involved small sample sizes and were largely based on women. Importantly one study did not feature a control group (Napolitano et al., 2013) limiting the ability to determine the impact of avatar technology. Only three studies explored the medium to long-term or sustained effects of using avatar-based interventions as an adjunct to a weight-loss management programme and findings may reflect the novelty and current interest in the use of avatar technology rather than the influence of the technology itself. A strength of this review is the clear focus and comprehensive and easily replicable search strategy. Additionally, we systematically selected studies through the application of well-defined inclusion/exclusion criteria.

5. Conclusions

The use of an avatar appears to be a useful adjunct to a weight loss management programme among individuals who are obese or overweight. Furthermore, personalisation of an avatar appears to demonstrate some additional benefits by engaging and retaining interest and motivation to comply with a weight loss programme. Future research should use more robust designs following the Medical Research Council's framework for developing complex interventions (Campbell et al., 2007) to ensure a robust evidence base for avatar implementation is developed. The evidence presented in this review is not sufficiently strong to draw conclusions as to the clinical efficacy and acceptability of avatars in weight management due to the heterogeneity in study design and reporting. However, the evidence does not suggest that the use of avatar technology is ineffective and, therefore, is certainly worthy of further investigation as we move increasingly towards a digital reliant society.

Ethical approval

None sought.

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Declaration of competing interest

The authors declare that there is no conflict of interest.

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