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ORIGINAL PAPER

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Virtual reality in mental health

A review of the literature

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Abstract *Background* Several virtual reality (VR) applications for the understanding, assessment and treatment of mental health problems have been developed in the last 10 years. The purpose of this review is to outline the current state of virtual reality research in the treatment of mental health problems. *Methods* PubMed and PsycINFO were searched for all articles containing the words "virtual reality". In addition a manual search of the references contained in the papers resulting from this search was conducted and relevant periodicals were searched. Studies reporting the results of treatment utilizing VR in the mental health field and involving at least one patient were identified. *Results* More than 50 studies using VR were identified, the majority of which were case studies. Seventeen employed a between groups design: 4 involved patients with fear of flying; 3 involved patients with fear of heights; 3 involved patients with social phobia/public speaking anxiety; 2 involved people with spider phobia; 2 involved patients with agoraphobia; 2 involved patients with body image disturbance and 1 involved obese patients. There are both advantages in terms of delivery and disadvantages in terms of side effects to using VR. Although virtual reality based therapy appears to be superior to no treatment the effectiveness of VR therapy over traditional therapeutic approaches is not supported by the research currently available. *Conclusions* There is a lack of good quality research on the effectiveness of VR therapy. Before clinicians will be able to make effective use of this emerging technology greater emphasis must be placed on controlled trials with clinically identified populations.

Key words virtual reality – simulations – exposure therapy – mental health

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Introduction

Virtual reality integrates real-time computer graphics, sounds and other sensory input to create a computer-generated world with which the user can interact. The virtual environment is presented not on a computer screen but through a head mounted display (HMD), typically either a helmet or goggles containing two small television screens along with stereo earphones. The user can explore and navigate in the virtual world by means of motion tracking devices attached to the HMD (and sometimes hands or feet), which enable the computer to adapt the field of view to the user's movements. A successful virtual experience provides the user with a *sense of presence*—as though they are physically immersed in the virtual environment. This sensation is achieved by shutting out 'real world' stimuli so that only computer-generated stimuli can be seen and heard. Some versions of the technology also provide haptic feedback via input devices like data gloves. The use of multiple sensory modalities including sound, touch and smell add a further element of reality to the experience.

There are a number of VR systems available commercially. Costs vary from a few hundred to a few thousand pounds (plus the cost of a computer), depending on the complexity of the VR and the type and quality of the hardware used. The minimum requirements are a Pentium IV computer with suffi-

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cient processing power (typically 2 GHz), memory (40 GB) and sound and graphics capability in addition to the head mounted display and position trackers. VR environments can be bought or licensed from developers and some developers have made their software freely available online. Clinicians may even choose to create and adapt their own virtual reality environments using commercially available 3D software packages.

VR technology has advanced rapidly since the first mental health application. Today's computers are much faster and the quality of head mounted displays has greatly improved. Perhaps more importantly, the cost of the technology has reduced significantly and as a result more applications are being developed. The main focus of VR is interaction and it may be assumed that as the technology improves and enables greater interaction that the effectiveness of VR as a therapeutic tool should also increase. However, even 'low tech' environments (e.g. computer game based VR) have had beneficial results [9] Participants are already being affected by the environments, even though they know they are not real [63].

A number of VR applications have been developed for use in the mental health field including applications for the treatment of specific phobias such as fear of flying [31, 52], fear of heights [24, 48], fear of spiders [5, 13] and cockroaches [4]. Other virtual reality applications have been developed for the treatment of post-traumatic stress disorder [8], male sexual dysfunction [36], attention deficit disorder in children [45] and test anxiety [34]. VR applications to assist in the cognitive assessment and rehabilitation of patients with traumatic brain injury and stroke [26], dementia [11] and schizophrenia [25, 67] have also been developed. The theoretical benefits of virtual reality based therapy are clear, particularly for anxiety disorders. Like the traditional approaches, VR based therapy for anxiety disorders is based on the principle of exposure. For some conditions in vivo exposure is impractical, difficult, and potentially dangerous (e.g. driving phobia) whilst for others the cost is prohibitive (e.g. flight phobia) and virtual reality may offer a safe and cost-effective alternative. Like imaginal exposure, VR exposure takes place in a controlled environment (usually the therapist's office) and because the patient does not have to be exposed to real situations for a fear response to be provoked, confidentiality is maintained. VR exposure may be perceived as safer than in vivo exposure as the patient knows that the technology can be switched off at any time. Feeling in control of the VR experience may serve to increase patients' feelings of self-efficacy. Moreover, a medium that is less aversive to phobic patients may increase the number of patients seeking treatment and decrease attrition rates. The majority of VR environments are also flexible: the therapist can readily adapt the experience to individual fear hierarchies. Virtual reality can also be used to recreate situations that cannot be re-experienced in vivo such as combat situations or the attack on the World Trade Centre and may be particularly useful for patients with post-traumatic stress disorder (PTSD). VR exposure may be used as an alternative to imaginal exposure in these situations meaning that patients need not rely on internal imagery or their ability to visualize. Furthermore, in imaginal exposure the therapist has no control over, or even knowledge of, what imagery the patient actually evokes whereas in the virtual environment the stimuli the patient is being presented with are controlled. As with phobic patients, VR based exposure therapy may be particularly useful for patients with PTSD for whom avoidance and failure to engage with therapy may hinder the therapeutic process [56].

Aims

This article reviews studies which have utilized virtual reality (VR) technology in the treatment of mental health disorders and discusses the clinical implications of these findings. Although a number of other reviews have been written [14, 15, 23, 38–41] there is a clear need for a fresh look at the existing evidence. The earlier reviews have concluded that a VR version of exposure therapy is effective but none have subjected the available data to Meta analysis nor quality assessed the studies that have been published. Significantly, there is a need for independent review separate from the developers of the commercially available virtual reality systems.

We ask whether there is any evidence that a VR version of exposure therapy is effective and after assessing the quality of the research conducted to date, make a number of recommendations for future VR research.

Methods

Studies for review were identified following a keyword search for the term "virtual reality" in two main abstract databases: PsycINFO, the American Psychological Association's abstract database and PubMed (published by the U.S. National Library of Medicine). PubMed was chosen because it provides access to bibliographic information from MEDLINE, which provides coverage of the fields of medicine, nursing, dentistry, the health care system, and the preclinical sciences and because it also contains in-process citations. In addition, the bibliographies of articles were examined in order to identify further citations. The contents pages of journals that were known to publish papers on virtual reality were also searched including: Cyberpsychology and Behavior, The International Journal of Virtual Reality and Studies in Health Technology and Informatics. All case and pilot studies, open trials and randomised controlled trials (RCTs) which utilized VR treatment were identified. The quality of the RCTs was assessed using the Clinical Trials Assessment measures (CTAM) [57] and the results of these RCTs were included in a Meta analysis.

Results

The database searches resulted in a total number of 3036 articles published between 1985 and April 2006 (final search conducted 26th April 2006): 1373 from PsycINFO and 1663 from PubMed. From these and the additional hand searches more than 50 studies using VR based treatment with at least one patient were identified. Seventeen of these studies compared the effectiveness of VR treatment with in vivo exposure, another treatment or a no treatment control. We present the results of these 17 (see Table 1) along with some key case and pilot studies in the following section.

Fear of heights

The very first VR studies in the mental health field were conducted with individuals with height phobia in the mid to late 1990s [6, 17, 48, 49]. These provided the first evidence that fear of heights could be reduced using virtual reality. The first controlled study was conducted by Rothbaum et al. in 1995 [49]. In this study 20 college students who met DSM-IV criteria for fear of heights were randomly assigned to virtual reality graded exposure treatment ($N = 12$) or to a waiting list control group ($N = 8$). The students assigned to the treatment group attended seven weekly sessions of VR exposure treatment. Three different situations (a footbridge, an outdoor balcony and a glass elevator) were presented with increasing levels of difficulty (e.g. balcony on the ground, tenth and twentieth floors). Ten participants completed the VR treatment. They showed significant improvements in anxiety, avoidance, attitudes and distress associated with exposure to heights in contrast to the seven remaining waiting list group participants who did not improve. Whether these results were solely due to the VR exposure is unclear as seven of the ten students who completed the therapy also carried out self-directed in vivo exposure during the treatment period.

Emmelkamp et al. [9] conducted the first study to compare VR exposure with another treatment. Using a within group design, VR was compared with in vivo exposure in 10 patients with fear of heights. Participants were treated with two sessions of VR exposure therapy followed afterwards by two sessions of in vivo exposure. Both treatments led to a significant improvement in anxiety. VR also led to improvements in avoidance and 'attitude towards heights'. Results were maintained at the 6 months follow up. It was concluded that VR exposure was as effective as exposure in vivo, but the order effect in this study (all participants underwent VR exposure before in vivo exposure) makes the results difficult to interpret.

A further study compared VR with exposure in vivo with a between group design [10]. In this study 33 patients were randomly assigned to either exposure in vivo ($N = 16$) or VR exposure ($N = 17$). Both groups received three 1 h weekly treatment sessions. Improvements in anxiety and avoidance occurred between over treatment for both groups and were maintained at 6 months follow up. VR exposure was found to be as effective as exposure in vivo on levels of anxiety and avoidance.

In the only study to compare different types of VR exposure 37 patients with height phobia were randomly assigned to one of 3 groups: (1) VR based exposure therapy using an HMD, (2) VR based exposure therapy using a CAVE™ environment[1] or (3) waiting list control [24]. No differences were found between groups 1 and 2 but both were superior to the waiting list. Results were maintained at the 6 months follow up. Interestingly, the patients undergoing exposure therapy using the CAVE system did not show superior outcomes despite experiencing greater presence.

Flying phobia

As with height phobia, a number of case studies using VR applications for flight phobia have been reported [21, 32, 52, 53, 65]. In a pilot study, VR was combined with cognitive behavioral therapy (CBT) to treat fear of flying in 31 patients [19]. Over half of the participants had a fear of a crash while the rest suffered from claustrophobia, fear of heights or panic disorder with agoraphobia. Patients were taught relaxed breathing and cognitive strategies prior to exposure to flight scenarios. When the therapist determined that the patient had received maximum benefit from the VR exposure it was suggested that they take an actual flight. The criteria for improvement were whether or not the patient flew after treatment. Twenty-one patients (67.7%) achieved this goal. It is difficult to interpret these results as the authors do not report on either subjective or objective anxiety levels before, during or after exposure, nor did they include a control group for comparison. Furthermore they report that 10 patients received other cognitive behavioral treatment during their VR treatment and 5 began medication (benzodiazepines) whilst in treatment.

Four controlled studies utilizing VR therapy with fear of flying patients have been conducted to date. In the first of these Rothbaum et al. [51] randomly assigned 49 patients with fear of flying to either VR exposure, 'standard' exposure therapy (SE) or a waiting list control. Fifteen subjects in each group completed treatment. Treatment consisted of 8 sessions over 6 weeks with 4 sessions of anxiety management training followed by either 4 twice weekly sessions of exposure to a virtual airplane or exposure

[1] The 'Cave Automatic Virtual Environment' (CAVETM) dispenses with the HMD completely and uses stereoscopic projection to display images on the surrounding walls and floor.

Table 1 Controlled trials

Author and year of publication	Condition being treated	Sample	*N*	Therapy type/duration	Comparison	Outcome (effect size)
Rothbaum et al. (1995)	Fear of heights	Students	20	VR exposure (7 × 35–45 min)	Waiting list (NT)	VR > NT (2.19)
North et al. (1995)	Agoraphobia	Students	60	VR exposure (8 × 15 min)	No treatment (NT)	VR > NT (3.20)
Harris et al. (1997)	Public speaking anxiety	Students	17	VR exposure (4 × 12–15 min)	No treatment (NT)	VR > NT (1.82)
North et al. (1997)	Fear of public speaking	Students	16	VR exposure (5 × 10–15 min)	Self directed visualization or self exposure (SDV)	VR > SDV (3.23)
Rothbaum et al. (2000)	Fear of flying	Volunteers and referred patients	49	VR exposure (8 sessions[a])	a) in vivo exposure (IV) (8 sessions[a])	VR = IV (0.03)
					b) No treatment (NT)	VR > NT (0.65)
Wiederhold et al. (2001)	Fear of flying	Volunteers and referred patients	30	a) VR exposure with physiological feedback (8 sessions[a])	Imaginal exposure (IE) (8 sessions[a])	a)VR > IE (0.42)
				b) VR without physiological feedback (8 sessions[a])		b)VR > IE (1.05)
Riva et al. (2001)	Body image disturbance in obesity	Clinic attendees	28	VR therapy (7 × 50 min)	CBT based 'psychonutritional' group (CBP) tri-weekly sessions for an average of 6.5 weeks[a]	VR > CBP*
Riva et al. (2002)	Body image disturbance in binge eating disorders	Clinic attendees	20	VR therapy (7 × 50 min)	CBT based 'psychonutritional' group (CBP) tri-weekly sessions for an average of 6.5 weeks[a]	VR > CBP*
Garcia-Palacios et al. (2002)	Spider phobia	Students and volunteers	23	VR exposure[a b]	No treatment (NT)	VR > NT (2.39)
Maltby et al. (2002)	Fear of flying	Volunteers	45	VR exposure 1 × 90 min, 5 × 50 min	'attention-placebo group treatment' (APGT) 1 × 90 min, 5 × 50 min	VR > APGT (0.78)
Emmelkamp et al. (2002)	Fear of heights	Volunteers	33	VR exposure 3 × 60 min sessions	in vivo exposure (IV) 3 × 60 min sessions	VR = IV (0.32)
Hoffman et al. (2003)	Spider phobia	Students	36	a) VR exposure with tactile cues (VRT) (3 × 60 min)	No treatment (NT)	a) VRT > NT*
				b) VR exposure without tactile cues (VR) (3 × 60 mins)		b) VR > NT*
Muhlberger et al. (2003)	Fear of flying	Volunteers	58	VR based cognitive treatment (VR) (1 × 140 mins)	a) No treatment (NT)	a)VR > NT (1.85)
					b) Cognitive treatment alone (CT) (1 × 60 mins)	b) VR > CT (1.08)
Vincelli et al. (2003)	Panic disorder with agoraphobia	Clinic attendees	12	VR assisted cognitive behavioural therapy (VRCBT) (8 sessions[a])	a) No treatment (NT)	a) VRCBT > NT (0.72)
					b) CBT with imaginal exposure (CBTIE) (12 sessions[a])	b) VRCBT > CBT (0.85)
Krijn et al. (2004)	Fear of heights	Clinic attendees	37	a) VR exposure (3 × 90 mins)	No treatment (NT)	VR > NT (0.52)
Klinger et al. (2004)	Social phobia	Clinic attendees	36	VR exposure (12 × 45 mins)	Group CBT (GCBT) (12 sessions[a])	VR = GCBT (0.12)
Riva et al. (2006)	Obesity	Clinic attendees	211	VR therapy (20 × 60 mins)	Nutritional group (N) (5 sessions) CBT group (CBT)([20] sessions) No treatment (NT)	VR > CBTP*

Notes [a] Duration of sessions not reported; [b] Number of sessions not fixed/reported, * means and SDs not reported: effect size not calculated to an actual airplane at the airport. The VR exposure consisted of sitting in an airplane; experiencing take off and landing and flying in both calm and stormy weather. Standard exposure was conducted at the airport on a stationery plane. Patients' willingness to fly was measured by a post-treatment flight on a commercial airline. Both types of exposure were found to be superior to the waiting list control but there were no differences between VR exposure and in vivo exposure. The 12 months follow up obtained data on 24 of the 30 participants who completed either VR or standard exposure therapy [47]. Treatment gains were maintained: 12 of 13 (92%) from the VR group and 10 of 11 (91%) from the SE group had flown since completing treatment although a significant number reported using either alcohol or drugs to reduce anxiety on flights. It was concluded that no relapse or booster sessions were necessary after VR exposure therapy and that short-term treatment had lasting effects.

Thirty patients with flight phobia were randomly assigned to complete either one VR test flight followed by four VR exposure flights in one lengthy session or to complete one VR test flight followed by a lengthy relaxation session [29]. All participants also completed a second VR test flight at the end of the session. Attenuation of fear responses occurred for both groups but fear reduction associated with VR exposure was greater.

In a later study [30] the efficacy of a one-session VR exposure treatment was examined. Forty-five patients with flight phobia were randomly assigned to either: cognitive treatment plus VR exposure with motion simulation; cognitive treatment plus VR exposure without motion simulation or cognitive treatment alone. Post-treatment and 6 months follow ups recorded reduced fear of flying in both VR exposure groups but not in the cognitive treatment group. The results of the two VR groups were comparable indicating that motion simulation does not enhance treatment effects.

Another study [64] compared virtual reality graded exposure therapy (VRGET) with standard graded imaginal exposure in flight phobics. Thirty subjects were randomised into one of three conditions: VRGET with physiological feedback; VRGET with no physiological feedback or imagery. After two relaxation sessions and six exposure sessions 80% of the VR patients who weren't receiving physiological feedback and 100% of those who were, were able to fly without medication, in contrast to just 20% of those receiving imagery. At the 3 years follow up [66] all the participants in the VRGET with physiological feedback had maintained their ability to fly without the use of medication or alcohol to control anxiety; whilst two of those in the VRGET without feedback group who were able to fly after the initial intervention were no longer able to fly (20% recidivism rate).

In the most recent study, and the only one to take account of nonspecific treatment effects, 45 patients with flight phobia were randomly assigned to five sessions of VR exposure or attention-placebo group treatment [28]. At post-treatment 65% of VR participants and 57% of participants in the attention-placebo group flew during a test flight. Both groups reported improvements on subjective measures of anxiety with a significantly better outcome for the VR group on 4 out of 5 of the measures. At 6 months follow up however, most group differences had disappeared; with VR significantly better on just 1 of the 5 anxiety measures.

Driving phobia

Although several attempts to use VR to treat driving phobia have been made there has not been a controlled trial of the efficacy of VR for this diagnostic group to date. Wald and Taylor [61] report on five patients with driving phobia who were treated with 8 weekly VR exposure sessions. Three of the 5 patients showed a clear improvement in driving anxiety and avoidance and no longer met criteria for driving phobia by the end of therapy. Significantly, however, there was little change in actual driving frequency for any of the patients. There was some loss of treatment gains at the 3 months follow up for the three who had improved by post-treatment but the scores were still below their pretreatment levels. Two of the three who had shown an improvement were included in the one year follow up where treatment gains were reported to have been maintained although one of the two was unable to drive "due to personal stressors unrelated to her driving fear" [60]. The authors concluded that VR exposure may not be sufficient for some patients, and although they stopped short of stating that simulated driving environments are not 'real enough' for this type of phobia, they suggest that VR exposure may need to be followed by a course of in vivo exposure.

Walshe et al. [62] demonstrated the difficulty of successfully immersing patients in a simulated driving environment in their open trial of virtual reality and "game reality" in 14 patients with driving phobia following a motor vehicle accident. Subjects were consecutive accident/emergency and GP referrals to a trauma clinic. Of the 14, half did not demonstrate an anxiety response on exposure to the simulated driving environment and therefore had to be excluded from the treatment phase of the study. The remaining 7 patients were exposed to a cognitive behavioural program of up to 12 1-hour sessions involving graded driving simulations tasks. VR generated scenes involved the participant driving in a city scene, in open country and through a tunnel. As they became more comfortable, participants were set tasks such as overtaking, negotiating obstacles and finally, crashing into other vehicles. In addition, subjects were taught diaphragmatic breathing and cognitive restructuring. Homework was not set but participants were encouraged to drive 'to the degree that they felt comfortable'. Pre- and post-treatment comparisons showed significant post-treatment reductions on measures of distress, fear of driving, post-traumatic stress and depression.

In a more recent study Walshe et al. [63] achieved an immersion rate of 91% with 11 clinically referred patients using a VR treatment paradigm which included a projector screen, windscreen, passenger seat and vibrating subwoofers placed under the feet.

Spider phobia

Garcia-Palacios et al. [13] developed a VR application for the treatment of spider phobia. About 23 college students were assigned to either VR exposure or to a waiting list control group. The number of sessions was not fixed: the treatment was deemed to be complete when the participants could, after gradual exposure, hold a virtual tarantula with tactile feedback whilst reporting low levels of anxiety. The average number of sessions required before this goal was reached was 4 (range 3–10). About 83% of the VR group showed clinically significant improvement compared with none in the waiting list group. Improvement in the VR group generalized to the real world: after treatment, patients were able to approach a live tarantula with only low to moderate levels of anxiety. However, as no follow up was conducted it is not known whether the treatment effect was maintained.

In a later study [18] 8 phobic & 28 non-phobic students were randomly assigned to one of 3 groups: no treatment, VR with no tactile clues, VR with tactile clues ('virtual spider').

Participants in the two VR groups received three 1-hour VR exposure sessions. Both groups reported clinically significant reductions in behavioural avoidance and subjective fear with the tactile augmentation group showing the greatest progress.

Social phobia

Although it is difficult to accurately represent humans in the virtual world a number of studies have shown that simulated humans (avatars) can elicit the kind of fear that people experience in social situations [37]. A number of studies have demonstrated some success in alleviating public speaking anxiety [1, 16, 33, 35, 37] and generalized social anxiety [22].

North et al. [33] allocated sixteen students to either VR therapy ($N = 8$) or a comparison group ($N = 8$). The VR group was exposed to a public speaking environment while the comparison group was exposed to a 'trivial' VR scene and were encouraged to manage their phobia using visualization techniques or self exposure to the feared situations. The VR environment used for the VR group was a virtual auditorium, which included a virtual wooden podium and a speaker's stand. Participants were asked to speak into a microphone attached to the HMD, which simulated echo in the auditorium. They underwent 5 weekly 10–15 min sessions. The VR group experienced a significant reduction of anxiety symptoms and an increased ability to face real world situations. In contrast, the comparison group did not show significant changes.

Harris et al. [16] recruited students from public speaking classes into a VR treatment program. Ten were assigned to the treatment group and 8 to the waiting list group. The treatment was brief, consisting of just four 12–15 min sessions but the VR group showed a significant reduction in anxiety.

Klinger et al. [22] compared VR therapy to cognitive behavioural group therapy (CBGT) in a recent clinical trial. 36 patients with social phobia were recruited. The 18 patients in the VR group attended 12 weekly 45 min sessions of therapy. VR took up 20 min of these sessions. Patients were exposed to four separate environments: a performance environment where the patient learnt to speak in public; an intimacy environment where the patient learnt to establish contact with others; a scrutiny environment, where the patient learnt to move and speak while under scrutiny and finally an assertiveness environment in which the patient learnt to protect his/her own interests (by having to confront people who criticized him/her or who blocked his/her way). After each session, the patients in both groups carried out tasks in vivo to practice what they had learned during their sessions. VR exposure was reported to be as effective as CBGT at improving anxiety but statistical comparisons between the two groups were not made. A major flaw in the study was the failure the randomly allocate participants.

Although avatar technology is in its infancy, there is good evidence to suggest that people attribute mental states to virtual reality characters. Freeman et al. [12] exposed 24 non-clinical participants to a neutral virtual environment containing computer-generated people (a library) and assessed the extent to which they experienced paranoia and persecutory ideation about the VR characters. The VR library was displayed using a CAVE system and contained five avatars. Participants spent 5 min in the virtual environment and were asked to "form some impression of what you think about the people in the room and what they think about you". The behaviour displayed by the avatars was ambiguous (e.g. smiling, looking, and talking to each other) and accordingly, the majority of participants viewed the avatars as benevolent. However some individuals had thoughts of a persecutory nature. For example, 9 of the 24 (37.5%) agreed with the statement "Someone in the room had it in for me" and 12 (50%) endorsed "they were talking about me behind my back". Examples of comments made by the participants include: "they were ignorant and unfriendly" and "some were intimidating". Additionally, higher levels of anxiety and interpersonal sensitivity were significantly related to persecutory ideation. The authors concluded that VR may be used to help patients evaluate and reduce persecutory ideas.

Panic and agoraphobia

Sixty subjects with agoraphobia were allocated to either VR therapy ($N = 30$) or a no treatment control group ($N = 30$) [31]. Therapy consisted of 8 weekly 15 min sessions. At the end of treatment negative attitudes toward agoraphobic situations decreased for the VR group but not for the control group. No other outcome measures were assessed.

Vincelli et al. [59] randomised 12 patients with DSM-IV diagnosed Panic Disorder and Agoraphobia to either (a) 'Experiential-Cognitive Therapy' (ECT: a VR assisted cognitive-behavioral therapy; (b) CBT with imaginal exposure or (c) waiting list control group. Patients undergoing ECT were exposed to 8 VR sessions in which four virtual situations were presented: an elevator, a supermarket; a subway and a large open square. The number of computer-generated people (avatars) in the simulation (i.e. from none to a crowd) was manipulated by the therapist. In contrast to the waiting list group both the ECT and CBT groups achieved clinically significant improvements and while both ECT and CBT decreased depression, anxiety and the number of panic attacks ECT achieved this with 33% fewer sessions (8 versus 12 sessions) suggesting an economic advantage of using VR.

Post-traumatic stress disorder

VR exposure was used to treat 10 Vietnam combat veterans with (DSM-IV diagnosed) PTSD [50]. Participants were exposed to a virtual jungle clearing and a virtual helicopter. Audio effects included jungle sounds, gunfire, helicopters flying overhead and men shouting. Treatment typically consisted of ten 90 min sessions conducted twice weekly over a 5–7 week period (with a range of 8–16 sessions). Patients were asked to describe in detail the memories triggered by the virtual environments after the first three sessions and the remaining sessions were spent exposing patients to the virtual environments plus imaginal exposure to their most traumatic memories. Both clinician-rated and self reported PTSD symptoms were significantly reduced at 6 months follow up.

Difede and Hoffman [8] report a case study of PTSD resulting from the 9/11 attack on the World Trade Centre (WTC) who had failed to engage in traditional imaginal exposure. Over the course of six 1-hour sessions the patient was systematically exposed to virtual planes flying over the WTC, crashing into the WTC, virtual people jumping from the WTC, and finally, the towers collapsing. They report a large (90%) reduction in PTSD symptoms after the completion of therapy.

More recently, Rizzo et al. [46] have reported on the development of a VR application for Iraq War military personnel with PTSD.

Body image disturbance

In a controlled clinical trial 28 obese females who were involved in a residential weight control treatment were randomly allocated to either VR treatment or to 'psychonutritional' groups based on a cognitive-behaviour approach [42]. All patients were eating a restricted calorie diet and were engaged in physical training. Patients in the VR group experienced greater improvements in body satisfaction, self-efficacy and motivation for change than the 'psychonutritional' group. Unfortunately this study did not involve a follow up so maintenance of improvement was unknown.

In a similar study Riva et al. [43] randomly allocated 20 women with binge eating disorder to either a VR based therapy, CBT based psychonutritional groups. Although the VR based therapy was more effective in improving body image satisfaction, self-efficacy and motivation for change it was no more effective at reducing binge-eating behaviour.

Riva et al. [44] have recently conducted the largest randomised controlled trial to date with 211 morbidly obese patients. Like the earlier studies this trial compared Experiential Cognitive Therapy (CT) with nutritional (NT) and cognitive-behavioral (CBT) approaches along with waiting list controls. Participants in the NT group attended 5 weekly nutritional groups held by dieticians. CBT participants underwent the same treatment as the NT group plus 15 additional sessions over 6 weeks. The CT group also underwent the same treatment as the NT group plus 15 additional sessions, which included ten 60 min bi-weekly virtual reality sessions. The VR environments presented situations related to obesity maintenance and relapse mechanisms (e.g. gym, swimming pool or beach) and two body image comparison areas. Each of the three treatment groups resulted in significantly greater weight loss than the waiting list participants but there was no difference in either weight loss, or the main psychology variables (e.g. anxiety and body satisfaction). At the 6 months follow up experiential CT, in contrast to the other approaches, resulted in improvements in the level of body image satisfaction and self-efficacy.

Trial quality

The studies detailed above outline the potential utility of VR based approaches in the treatment of a number of mental health disorders. VR technology appears to be acceptable to the majority of patients and the treatment gains demonstrated indicate that VR environments are capable of evoking the anxiety responses necessary for exposure to be effective. The authors of these studies are uniformly positive about the potential benefits of VR and all of the controlled trials report VR based approached to be superior to no treatment and at least as effective as in vivo exposure/other alternative treatment approaches. However, it is clear that some of the studies were poorly designed and a formal assessment of trial quality is required before efficacy can be assessed. We used the clinical trials assessment measure (CTAM) to assess the quality of the 17 controlled trials. The CTAM consists of 15 differentially weighted questions in six areas of trial design: sample size and recruitment method; allocation to treatment; assessment of outcome; control groups; description of treatments and analysis (see Table 2). Authors of the included trials were contacted in cases where there was insufficient information available in the written report to make a rating. The maximum achievable score on the CTAM is 100 and in this sample of 17 trials the mean CTAM score was 37.4 (SD 14.8) with a median of 32 and a range of 16 to 71 (see Table 2). Considerable variability in methodology was evident. All, except two trials, had fewer than 27 participants in each treatment group, the minimum recommended to show a treatment effect [20]. Thus, the majority of studies were probably underpowered. Eleven of the 17 were based on highly selective samples: college students or volunteers recruited through advertisements offering free treatment. Although fourteen claim to have randomised participants to conditions only one contained the details of that randomization and for the remainder it is not known whether randomization was independent of the research team. Only three conducted assessments blind to treatment allocation and none described the blinding procedure or whether blinding was verified. In the majority of these studies analysis was frequently by completion of treatment and not as randomised (i.e. on an intention to treat basis). The therapy itself was often poorly described hindering direct comparisons of study outcomes.

It is interesting to note that the majority of the trials compared virtual reality approaches to waiting list controls rather than the accepted standard treatments (i.e. CBT, imaginal or in vivo exposure) and it is particularly striking that only one study has compared VR with imaginal exposure [64] given that the main clinical use of VR may be as a replacement for imaginal exposure when in vivo exposure is difficult or inappropriate. Because the control groups were not equivalent a single Meta analysis of the 17 trials was not possible. Instead two separate analyses were conducted: In the first, all of the studies comparing VR based exposure with a waiting list/no treatment control were included and in the second all of the studies

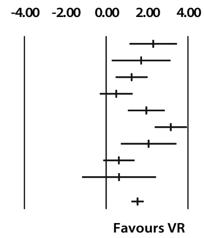
Table 2 CTAM scores

CTAM item	Rothbaum et al (1995)	North et al (1995)	Harris et al (1997)	North et al (1997)	Rothbaum et al (2000)	Wiederhold et al (2001)	Riva et al (2001)	Riva et al (2002)	Garcia-Palacios et al (2002)	Maltby et al (2002)	Emmelkamp et al (2002)	Hoffman et al (2003)	Muhlberger et al (2003)	Vincelli et al (2003)	Krijn et al (2004)	Klinger et al (2004)	Riva et al. (2006)
Q1 Sample not volunteers or students?							✔	✔						✔	✔	✔	✔
Q2 Sample size > 27 in each group?		✔															✔
Q3 Random allocation?	✔	✔			✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔		✔
Q4 Process of randomisation described?																	✔
Q5 Randomisation independent?																	✔
Q6 Independent assessors?							✔	✔						✔			✔
Q7 Standardised assessments?	✔	✔	✔		✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Q8 Blind assessments?							✔	✔						✔			
Q9 Blinding described?																	
Q10 Blinding verified?																	
Q11 TAU is a control or group controlling for non-specific effects?	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Q12 Appropriate analysis?			✔	✔	✔	✔			✔	✔	✔	✔	✔		✔		✔
Q13 Intention to treat analysis?	✔	✔				✔											
Q14 Treatment adequately described or protocol used?		✔	✔	✔	✔	✔	✔	✔	✔		✔	✔		✔	✔	✔	✔
Q15 Treatment quality assessed?																	✔
TOTAL CTAM	32	37	23	16	47	37	54	54	30	31	34	27	27	60	32	24	71

Fig. 1 VR compared to waiting list controls

Meta Analysis

Citation	EffectName	Year	N1	N2	Efftect	Lower	Upper	NTotal	PValue
Garcia-Palacios et al	VR v WL	2002	12	11	2.30	1.14	3.46	23	.00
Harris et al	VR v WL	1997	8	6	1.71	.27	3.15	14	.01
Hoffman et al	VR v WL	2003	24	12	1.24	.46	2.03	36	.00
Krijn et al	VR v WL	2004	17	11	.49	-.32	1.30	28	.20
Muhlberger et al	VR v WL	2003	26	10	1.96	1.06	2.87	36	.00
North et al	VR v WL	1995	30	30	3.16	2.37	3.95	60	.00
Rothbaum et al	VR v WL	1995	10	7	2.08	.71	3.44	17	.00
Rothbaum et al	VR v WL	2000	15	15	.62	-.15	1.39	30	.09
Vincelli et al	VR v WL	2003	4	4	.63	- 1.18	2.44	8	.35
Fixed Combined(9)			**146**	**106**	**1.53**	**1.23**	**1.84**	**252**	**.00**



comparing VR based exposure to an alternative treatment approach bar one were included. (The trial conducted by North et al. [32] did not use a comparable standardized assessment measure and was therefore excluded from this analysis). The individual effect sizes for each study (with the exception of [42, 43] for which means and standard deviations were not available) are reported in Table 1. The Meta analyses were conducted using Comprehensive Meta Analysis™ [3]. The results of these two analyses (see Figs. 1 and 2) were very different. Although VR treatment was clearly superior to no treatment (effect size = 1.53, 95% CI 1.23–1.84) the effect size was much smaller for the trials comparing VR to standard treatments (effect size = 0.30, 95% CI = 0.01–0.58). There was also a non-significant trend ($r = -0.411$, $p = 0.09$) for the CTAM scores to be correlated with the study effect sizes indicating that the studies employing poorer methodology were more likely to overestimate the magnitude of the positive benefits of treatment.

Aside from the methodological limitations, one of the main problems with the studies published to date is the failure to describe which factors make for a successful VR experience (i.e. demographics and personality characteristics). In addition, only one long term follow up (>1 year) has been conducted [66], thus there is little evidence about long term effectiveness and how well treatment effects generalize to the real world. The pace at which patients' progress through virtual therapy varies a great deal [2]. Some patients experience immersions almost immediately, some require numerous sessions and some do not experience it at all. Few studies have attempted to elucidate the factors involved. The number of VR sessions to be used often appears arbitrary and future research will need to detail the optimal number of sessions required for a treatment response.

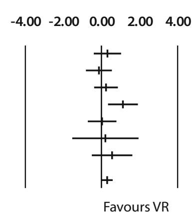
VR exposure does not occur in isolation and it is necessary to be confident that gains after VR exposure are a result of the VR itself rather than due to other factors. Similarly, no-treatment controls are required to assess natural improvement without treatment. At present it is difficult to disentangle the effect of the therapy from the effect of the VR and from non-specific and placebo effects. As with exposure based therapy the mechanisms underlying therapeutic benefit is unclear, whether exposure to phobic stimuli brings about habituation of anxiety or whether improvement is mediated by cognitive processes, such as a re-appraisal of threat, control or self-efficacy. VR potentially provides a mechanism by which these problems can be further investigated.

There are a number of obstacles to be overcome before clinicians will be able to make good use of VR technology. In a preference study for treatment of PTSD with an analogue population traditional methods of treatment such as cognitive and exposure therapy were rated significantly more highly on ratings of preference and acceptability compared to VR [55], which suggests that new technology treatments such as VR may be less acceptable. Moreover, VR has a number of effects on users, some of which may be harmful or cause discomfort. Individuals most at risk of harm are those who suffer from panic attacks, those with medical problems such as heart disease or epilepsy and those who are taking drugs with major physiological and or psychological effects [54]. These patients should be identified and excluded during the screening process. Furthermore, a number of side effects of the VR environments have been reported. Virtual Environments can affect the motion detection system and may result in imbalance, nausea and motion sickness [58]. Simulator sickness is a specific form of motion sickness that is primarily visually induced. Blade and Padgett [2] describe simulator sickness as:

Fig. 2 VR compared to standard treatments

Meta Analysis

Citation	EffectName	Year	N1	N2	Effect	Lower	Upper	NTotal	PValue
Emmelkamp et al	VR v IVET	2002	17	16	.31	-.40	1.03	33	.37
Klinger et al	VR v CBT	2004	18	18	-.13	-.81	.54	36	.68
Mattby et al	VR v placebo	2002	20	23	.24	-.38	.86	43	.43
Muhlberger et al	VR v CT	2003	26	11	1.13	.34	1.91	37	.00
Rothbaum et al	VR v IVET	2000	15	15	.03	-.71	.78	30	.92
Rothbaum et al	VR v CBT	2003	4	4	.21	-1.53	1.95	8	.75
Wiederhold et al	VRno v IET	2001	8	9	.56	-.50	1.62	17	.24
Fixed Combined (7)			**108**	**96**	**.30**	**.01**	**.58**	**204**	**.04**



> "Various disturbances, ranging in degree from a feeling of unpleasantness, disorientation, and headaches to extreme nausea, caused by various aspects of a synthetic experience. Possible factors include sensory distortions such as abnormal movement of arms and heads because of the weight of equipment, long delays or lags in feedback, and missing visual cues from convergence *(when the left and right eye images become fused into a single image)* and accommodation *(change in the focal length of the eye's lens to maintain focus on a moving close object)*" [italics added]

In a series of experiments 80% of all participants reported an increase in sickness symptoms following immersions in a virtual environment [7]. For the majority this was a mild increase, which subsided after exiting the immersion. However, 5% could not complete the immersion because the effects were so aversive. Symptom onset typically occurred within 15 min of starting. In repeated trials, symptoms were worse during the first immersion and were negligible by the third. It was noted that participants who were experiencing sickness symptoms changed their behaviour whilst immersed (e.g. began to minimize their head movements) indicating that any sickness experienced may have an affect on performance in the virtual environment. In addition to simulator sickness, mild physical pain from the HMD was noted but these symptoms were not found to remain after immersion ended. The occurrence of any adverse effects associated with duration of use of the VR system may limit the time available for anxiety reduction to occur, for example through habituation, compared to more established treatment methods, such as prolonged exposure. Periods of brief exposure may risk sensitization rather than desensitization although there does not appear to any reports of this in the literature.

It has been recommend that exposure management protocols for patients and VR should include (a) screening procedures to detect people who may present particular risks (b) procedures for managing patient exposure to VR applications and (c) procedures for monitoring unexpected side effects [27]. Treatment protocols should also include procedures for temporary cessation of VR exposure if patients feel overwhelmed and are unable to continue. Similarly, procedures for if, how and when they should be re-introduced to VR environment should also be established.

Conclusions

As the studies outlined in this paper show, VR technology potentially provides a means for understanding, assessing and treating a number of clinical disorders. The potential benefits of VR are manifold: virtual environments are flexible and programmable and their use fits well within established psychological theory and practice. Patients are generally accepting of the technology and the evidence that people react in virtual environments as if they were real is compelling.

The earlier reviews [14, 15, 23, 38–41] were uniformly positive about the future potential of a VR based approach to mental health problems, describing the results of the early studies as promising. However, as we have already noted, these reviews were primarily descriptive; available data were not subjected to Meta analysis nor were the studies quality assessed. The authors of three of the reviews [15, 23, 40] nevertheless made claims for the efficacy of VR treatment. Glantz et al. [15] reported VR therapy to be more effective than in vitro therapy in the treatment of fear of flying. Krijn et al. [23] reported it to be as effective as exposure in vivo in treating fear of heights and fear of flying and Riva [40] noted the general efficacy of VR in the treatment of fear of heights, fear of flying, body image disturbances and binge eating disorders. In contrast, whilst recognizing that VR therapy appears to be superior to no treatment, we conclude that VR has not yet been shown to be superior to standards treatments as comparisons, either of advantage or equivalence, have not been made in trials of appropriate methodology, size and statistical power.

We also note that prospective patients may prefer tried and tested treatments over VR, at least until there is an established evidence base for the efficacy of VR. The evidence currently available from direct comparisons does not support substantial benefits of VR over standard treatments. Despite the massive potential for the use of immersive VR in mental health there are a number of problems currently limiting the broader application of this emerging technology and more research is needed, specifically, well controlled robust randomised trials with well described clinical protocols and long term follow ups are required if we are to draw firm conclusions about the efficacy of VR in the therapeutic situation.

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