Treatment of acrophobia in virtual reality: The role of immersion and presence

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Abstract

In this study the effects of virtual reality exposure therapy (VRET) were investigated in patients with acrophobia. Feelings of presence in VRET were systematically varied by using either a head-mounted display (HMD) (low presence) or a computer automatic virtual environment (CAVE) (high presence). VRET in general was found to be more effective than no treatment. No differences were found in effectiveness between VRET using an HMD or CAVE. Results were maintained at 6 months follow-up. Results of VRET were comparable with those of exposure in vivo (Cyberpsychology and Behavior 4 (2001) 335). In treatment completers no relationship was found between presence and anxiety. Early drop-outs experienced less acrophobic complaints and psychopathology in general at pre-test. They also experienced less presence and anxiety in the virtual environment used in session one as compared to patients that completed VRET.
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1. Introduction

Over the last few years, research has been done on the effects of virtual reality graded exposure therapy (VRET). Virtual reality (VR) integrates real-time computer graphics, body tracking devices, visual displays, and other sensory inputs to immerse individuals in a computer-generated

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virtual environment. In VRET patients are exposed to virtual anxiety provoking environments instead of real anxious situations.

Few controlled studies have evaluated the effectiveness of VRET on specific phobias.

Rothbaum, Hodges, Smith, Lee and Price (2000) investigated the effectiveness of VRET compared to standard exposure (SE) or a waiting period (WP) for patients fearful of flying. VRET and SE both included four sessions in which the rationale was explained and breathing techniques, cognitive restructuring and thought stopping was learned. The next four sessions differed between conditions: VRET concentrated on virtual exposure to (a) sitting in the airplane, (b) experiencing take-offs and (c) landings and (d) flying in different weather-types. SE concentrated on real exposure to the airport and pre-flight stimuli and exposure to a stationary airplane. VRET was found to be as effective as SE and both treatments were more effective than a waiting period. Gains maintained during treatment remained stable at 6- and 12-month follow-up (Rothbaum et al., 2000; Rothbaum, Hodges, Anderson, Price, & Smith, 2002). No conclusions can be drawn about the effectiveness of the VR exposure component by itself, unfortunately.

Mühlberger, Herrmann, Wiedemann, Ellgring and Pauli (2001) have also conducted a controlled study on the effectiveness of VRET on fear of flying. Four exposures of 16 min to a virtual flight were compared to relaxation training in a between-group design. Before and after treatment questionnaires and a virtual test flight were given to investigate the treatment effectiveness. Results of this study indicate that VRET was able to elicit fear responses in phobics (measured by SUDS, heart rate and skin-conductance), and these responses decreased within exposures and across repeated exposures. The reduction in fear responses induced by four VR exposure flights was comparable to or even greater than achieved with relaxation training. These two studies indicate that VRET can be an effective component in the treatment of flight phobia.

All other studies with multiple subjects have been conducted on acrophobia. The first study was done with students randomly assigned to either VRET or a waiting list control group (Rothbaum et al., 1995). VRET was found to be more effective than a waiting period without treatment. In another study on acrophobia (Emmelkamp, Bruynzeel, Drost & van der Mast, 2001) 10 patients were first treated with two sessions of VRET and afterwards with two sessions of exposure in vivo, the golden standard of treatment of phobias. VRET was found to be as effective as exposure in vivo. No firm conclusions could be drawn however, because of the order effect (first VRET than exposure in vivo). In the second study by the same research group a between group design was used (Emmelkamp et al., 2002). Acrophobic patients were treated either with VRET or exposure in vivo. The exact same locations used in exposure in vivo were used in virtual reality to create an optimal comparison between the two kinds of treatment. A significant decline in anxiety and (behavioural) avoidance was found for both three-session treatments. There were no differences in effectiveness. The results remained stable at 6-month follow-up. However, in these earlier clinical studies, no-treatment control groups were lacking.

VRET is based on the assumption that people feel 'present' in the virtual environment. Presence is defined as 'a psychological state or subjective perception in which, even though part or all of an individual's current experience is generated by and/or filtered through human-made technology, part or all of the individual's perception fails to accurately acknowledge the role of the technology in the experience. Except in the most extreme cases, the individual can indicate correctly that s/he is using the technology, but at "some level" and to "some degree", her/his perceptions overlook that knowledge and objects, events, entities and environments are perceived as if the technology was not involved in the experience' (Lombard, 2000).

It is held that only if a patient has the feeling to be more present in the virtual anxiety-provoking environment than in the real environment, s/he can experience anxiety. Immersion, the objective qualification of the VR-equipment, is of influence on presence (Schubert, Friedmann, & Regenbrecht, 2001).

The aim of the present experimental study was to compare the effectiveness of two kinds of pure virtual reality exposure therapy in a between group design with acrophobic patients. A waiting list control group was added to examine the effect of time on the severity of acrophobia.

Relatively cheap VR-equipment using a normal PC with head-mounted display (HMD) was used for treatment in one condition. This was compared to VRET using a very advanced computer automatic virtual environment (CAVE). It was predicted that the degree of presence would be significantly higher using the CAVE-type system than by using the HMD. Furthermore, it was investigated if higher presence would lead to more effective treatment.

2. Method

2.1. Design

Thirty-seven patients were randomly assigned to one of three groups: VRET using (1) an HMD or (2) a CAVE-system or (3) a waiting list control group. After an intake session and a behavioural avoidance test (BAT) patients received a pre-test followed by three weekly 1.5 h sessions of VRET or a waiting period of 4 weeks. One week after the last session or after a waiting period of 4 weeks the post-test was held. After the post-test patients in the waiting list condition were randomly assigned to three weekly 1.5 h sessions of VRET using either an HMD or CAVE, and were reassessed after the treatment period. A follow-up was held 6 months after treatment.

2.2. Participants

To participate in this project, all subjects had to meet current diagnostic and statistical manual of mental disorders (DSM-IV) criteria for specific phobia, naturalistic type (APA, 1994). Acrophobia had to be the main complaint. Patients who fulfilled the criteria of panic disorder and/or used tranquillizers or anti-depressants and/or wore glasses stronger than -3.5 were declined for treatment. Moreover patients had to be unable to complete the BAT at pre-test.

Thirty-seven patients were included after the intake and BAT. Twelve patients dropped out during the study because of various reasons; two because they could not find the time to participate in treatment and ten because VRET did not arouse anxiety (failures: n(CAVE) = 3; n(HMD) = 7). Five of these 10 subjects for whom VRET did not arouse anxiety, dropped out after the waiting period. However, the data of their pre- and post-tests (during the waiting period) were used for analysis. For ethical reasons VRET was discontinued and these 10 patients were offered treatment outside the experimental trial.

Thirty patients remained in the study (18 males, 12 females). Five patients dropped out after the waiting period. Twenty-two subjects completed the follow-up as well. The average age of these 30 patients was 50.6 years (S.D., 9.67). The duration of the acrophobia was 33.5 years (S.D., 13.26).

2.3. Treatment

Virtual reality graded exposure therapy with an HMD was given in a dark laboratory room at the department of Clinical Psychology of the University of Amsterdam. The virtual worlds were generated using a Pentium II 450 MHz Intergraph computer with 128 Mb RAM, 4 Gb hard disk, and two Intergraph Intense 3D Pro 2200 graphic cards, with 16 Mb texture memory. The software used was Sense 8 WorldUp R4, a commonly used VR modelling and visualization toolkit. In all the system was able to generate the display at a rate of about 15–20 frames per second. The worlds were displayed using the Cybermind Visette Pro. Projection was stereographic. The field of view was 70.5° diagonally. Tracking was done with Ascension Flock of Birds. Patients could walk around freely on 1 m². A railing the patient could hold on to bounded this area.

Virtual reality graded exposure therapy by means of the CAVE was given in a dark room at the department of Computer Science of the University of Amsterdam. The CAVE is a multi-user projection-based VR system. In the installation the patient and therapist are surrounded by stereoscopic computer generated images on four sides. Three of these 3×3 m images are rear-projected on screens, forming the front and sidewalls of the CAVE. The fourth image is projected on the floor from above.

An SGI Onyx2RealityMonster with eight processors generates the stereoscopic images in the CAVE. The InfiniteReality hardware is among the most powerful general-purpose graphics system available. The computer is equipped with four graphic pipes. The computer that serves the CAVE needs 1/60 of a second to generate two projections (left and right eye) for four walls. Patients wore Crystal Eyes LCD Shutterglasses that lightened and darkened in synchronization with the images on the screen. The synchronization signals were given from a number of infrared emitters placed around the CAVE. The CAVE used an Ascension Technologies Flock of Birds electromagnetic tracking system with a sensor attached to the user's shutter glasses to generate the correct perspective view.

Treatment consisted of three sessions of 1.5 h. In each session the patient was exposed to the virtual environment(s) for 1 h (with a 10-min break in the middle to avoid simulator sickness). The rest of the time was used for instructions, loading each virtual environment and filling in questionnaires. At the beginning of session one the rationale of the exposure-program was explained as also the operation of the system. Patients were introduced to virtual reality on ground level of the first virtual environment (VE). Four VEs were created for treatment and used in a gradual order; a shopping mall with four floors (Fig. 1), a fire escape with six floors in open space (Fig. 2), a roof garden on a building (Fig. 3) and a virtual building site with eight floors (Fig. 4).

To give patients a gradual and optimal exposure treatment, patients had to rate their anxiety regularly during the exposure therapy by means of SUDS (0–10). Patients were instructed during treatment to expose themselves to the anxiety provoking situations in a gradual manner. After habituation or a relatively low SUD (usually below two) patients were encouraged to take a next step (for instance move up one floor, or take their hands off the railing). Only exposure techniques were used and encouragement was given during treatment, no cognitive interventions or relaxation was given. Patients were instructed to become as involved as possible and focus on the most frightening stimuli of this particular part of the virtual environment (for example, looking down, describing the situation and their feelings). This was done to avoid dissociation from the VR

Fig. 1.   Virtual height environment: Shopping mall.

Fig. 2.   Virtual height environment: Fire escape.

experience. In order to study the effects of pure VRET, patients did not receive homework instructions, and practising in vivo between sessions at home was not encouraged.

2.4. Assessment

2.4.1. Intake

The section anxiety disorders of the structured clinical interview for DSM-IV Axis I Disorders (SCID-I) (First, Spitzer, Gibbon, & Williams, 1996) was used in the intake session. The symptom check list 90 revised (SCL-90) (Derogatis, 1997) was included as a screening instrument for
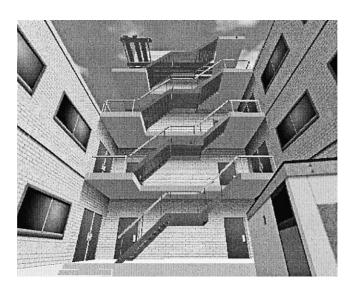
Fig. 3.   Virtual height environment: Roof garden.

Fig. 4.   Virtual height environment: Building site.

additional psychopathology. No subject had to be excluded because of severe additional psycho-pathology.

2.4.2. Pre-, post- and follow-up

Questionnaires were used to evaluate the effects of treatment. In addition a behavioural avoidance test (BAT) was conducted to measure avoidance behaviour in height situations before and after treatment (or a waiting period). The BAT consisted of walking a fire escape (with a maximum of six floors) as high as a patient was able to, while looking over a railing at ground level continuously. When a patient could not walk any further, because their anxiety became intolerable

or the stairs was finished, (s)he was instructed to come down on her/his own. The number of stairs a person had climbed was taken as outcome-measure (range 0–72).

All questionnaires were used before and after treatment (or a 4-week waiting period), at post-test and at follow-up (6 months later): (1) The acrophobia questionnaire (AQ) (Cohen, 1977) was used, measuring anxiety in height situations (range 0–20; $\alpha = 0.80$), and avoidance of height situations (range 0–40); $\alpha = 0.70$). (2) The attitude towards height questionnaire (ATHQ) (Abelson & Curtis, 1989) assessed the attitudes from the patients towards height situations (range 0–60; $\alpha = 0.81$).

2.4.3. Within sessions

In each session feelings of presence and state anxiety were measured twice, halfway through the session and after the session.

Presence was measured with the Igroup presence questionnaire (IPQ) (Schubert, Friedmann and Regenbrecht, 1999). State anxiety was measured in both conditions with the Dutch version of the state trait anxiety inventory (STAI; van der Ploeg, 1980).

3. Results

3.1. Waiting list vs. VRET

To investigate whether VRET was more effective than no-treatment, the HMD and CAVE subjects were pooled. Means and standard deviations are presented in Table 1. A 2 (time: pre vs. post) $\times$ 2 (condition: VRET vs. WL) MANOVA showed that there was a significant time-effect, $F(4,23) = 7.302$; $P = 0.001$ and interaction effect between time and condition, $F(4,23) = 4.040$; $P = 0.01$. Univariate analyses showed that this effect was significant on all main measures, namely the AQ-Anxiety, AQ-Avoidance, the ATHQ and the BAT (see Table 1). Thus VRET was

Table 1
Means (S.D.) of VRET and waiting list-condition and univariate analyses of time-effect and time $\times$ condition effect

Measure	Condition	Pre-test	Post-test	Time			Time $\times$ condition		
				F	df	P	F	df	P
AQ-Anxiety	WL	52.27 (17.95)	55.41 (13.53)	2.559	1, 26	0.122	7.304	1, 26	0.012
	VRET	59.71 (14.12)	47.47 (16.87)						
AQ-Avoidance	WL	14.91 (2.51)	14.00 (4.86)	18.94	1, 26	0.000	10.407	1, 26	0.003
	VRET	16.47 (5.94)	10.35 (4.47)						
ATHQ	WL	46.82 (9.70)	46.45 (10.49)	6.122	1, 26	0.020	5.484	1, 26	0.027
	VRET	47.11 (9.89)	33.88 (10.95)						
BAT	WL	34.64 (11.63)	35.00 (12.50)	13.487	1, 26	0.001	12.499	1, 26	0.002
	VRET	31.00 (14.12)	50.12 (21.50)						

n(WL) = 11; n(VRET) = 17. AQ-Anxiety, acrophobia questionnaire, anxiety scale; AQ-Avoidance, acrophobia questionnaire, avoidance scale; ATHQ, attitude towards heights questionnaire.

significantly more effective than no treatment. Comparison of the pre-test and the post-test of the waiting condition with paired *t*-tests, showed that there were no significant differences on any of the measures. The post-test of the waiting group could thus be taken as pre-test for the treatment received afterwards. Habituation effects to the BAT procedure can also be ruled out, because there were no differences whatsoever.

3.2. VRET: HMD vs. CAVE, pre-, post- and follow-up

Subjects who received treatment directly and those that received treatment after the waiting period were pooled into two groups (VRET/CAVE and VRET/HMD).

A 2 (time: pre vs. post) $\times$ 2 (VR type: HMD vs. CAVE) MANOVA revealed a significant time-effect, $F(4, 19) = 15.953$; $P = 0.000$, but neither a condition-effect, $F(4, 19) = 1.751$; $P = 0.181$, nor an interaction effect, $F(4,19) = 0.743$; $P = 0.574$. Means and standard deviations are presented in Table 2. Univariate analyses (see Table 2), revealed also that VRET was effective in the treatment of acrophobia and the equipment used did not make a difference in treatment effectiveness.

Between post-test and follow-up a significant time effect was found by means of a MANOVA for repeated measures ($F(3, 18) = 3.253$; $P = 0.046$). Univariate ANOVAs for repeated measures however, showed that this significant time effect was not found on any single measures (AQ-Anxiety: $F(1,20) = 0.346$; $P = 0.563$; AQ-Avoidance: $F(1,20) = 1.182$; $P = 0.290$; ATHQ: $F(1,20) = 1.846$; $P = 0.189$). This indicated that the gains made during treatment remained rather stable at 6-month follow up. No significant condition or interaction effects were found.

A univariate repeated measures analysis was done to investigate if there was any time or condition or interaction-effect on the IPQ. The results show that there was a significant condition-effect ($F(1, 20) = 8.024$; $P = 0.010$) which means that therapy given in the CAVE resulted in more presence than therapy given with an HMD. Means and standard deviations are presented

Table 2
Means (S.D.) of VRET/CAVE and VRET/HMD and univariate analysis of time-effect pre-post

Measure	Condition	Pre-test	Post-test	Time		
				F	df	*P*
AQ-Anxiety	CAVE	59.86 (13.72)	46.79 (18.11)	28.630	1, 22	0.000
	HMD	60.35 (13.78)	42.80 (13.07)			
AQ-Avoidance	CAVE	17.14 (6.01)	10.50 (5.10)	53.848	1, 22	0.000
	HMD	14.60 (4.20)	7.30 (3.43)			
ATHQ	CAVE	48.57 (8.83)	34.93 (12.00)	15.299	1, 22	0.001
	HMD	42.30 (11.28)	33.00 (6.75)			
BAT	CAVE	28.00 (11.33)	47.14 (19.92)	38.362	1, 22	0.000
	HMD	37.80 (13.64)	57.60 (17.71)			

n(CAVE) = 14; n(HMD) = 10 (missing data of one subject). AQ-Anxiety, acrophobia questionnaire, anxiety scale; AQ-Avoidance, acrophobia questionnaire, avoidance scale; ATHQ, attitude towards heights questionnaire.

in Table 3. Finally, no significant correlations were found between state anxiety and presence in any session.

Because of the relatively large amount of dropouts, these data were used to analyze the differences between drop-outs (failures) and clients that did finish the total VR-treatment (completers). Only those dropouts ($n=10$) were used that did not complete virtual reality treatment because no anxiety was provoked. On the pre-test data treatment completers scored significantly higher on the AQ-avoidance, $F(34) = 2.151$; $P = 0.04$, and a trend towards significance was found on the AQ-anxiety scale, $F(33) = 1.859$; $P = 0.07$. Completers also experienced more general psychopathology before treatment, measured with the SCL-90, than failures did; $F(25.37) = 2.254$; $P = 0.03$. Failures experienced significantly less presence during the first half of session one as compared to completers, $F(31) = 6.850$; $P = 0.0001$). A trend towards significance was found for state anxiety. Clients that completed treatment experienced more anxiety during the first half hour in session one than clients for whom treatment failed, $t(31) = 1.893$; $P = 0.07$.

4. Discussion

This is the first study in which VRET is compared with a no-treatment control group in clinically distressed patients with acrophobia. Only data from patients for whom VRET induced anxiety were used in the analyses comparing HMD vs. CAVE.

VRET was superior to no-treatment on anxiety, (behavioural) avoidance and attitudes towards heights. No differences in effect were found between VRET by means of CAVE (high presence induction) or HMD (low presence induction) and results remained stable up to 6 month follow-up.

Visual inspection of the means and S.D. at follow-up reveal that the HMD-condition showed a small decline in treatment effect while the CAVE-condition remained stable.

It must be noted that this study was conducted as an experimental trial to investigate if there were any differences in effectiveness between HMD and CAVE. It cannot be considered as a clinical trail per se. Nevertheless, looking at other studies on treatment of acrophobia, the effectiveness found in this study was in the same range as in the Emmelkamp et al. study (2002) where exposure in vivo was given in three sessions of 1 h each.

The role of presence in moderating successful outcome of VR treatment, so often assumed by different authors (Schubert, Friedman, & Regenbrecht, 1999; Schuemie et al., 2000; Wiederhold & Wiederhold, 2000), did not have any effect on treatment effectiveness in this study. Although the experimental manipulation (HMD vs. CAVE) was successful in creating different levels of presence, this did not lead to enhanced treatment outcome. There were no correlations found between

Table 3
Means (SD) of the IPQ-scores in session 1, 2 and 3

Total IPQ	Session 1	Session 2	Session 3
CAVE	63.79 (10.70)	63.96 (12.25)	62.50 (14.40)
HMD	52.90 (11.54)	48.75 (12.14)	51.35 (8.37)

n(CAVE) = 12; n(HMD) = 10. IPQ, igroup presence questionnaire.

presence and anxiety during the sessions. Some studies did find a linear relationship between presence and anxiety experienced (Schuemie et al., 2000), but others, like this study have not (Regenbrecht, Schubert, & Friedman, 1998).

Failures experienced less acrophobic complaints and psychopathology at pre-test (measured by means of the AQ and SCL-90) than did patients who finished therapy successfully. Further, failures experienced less presence and less anxiety in the first half of the first session. This could suggest that for less severe height-phobic cases VRET is not indicated. Taken together, it might be that some level of presence is necessary to generate anxiety, but a higher level of presence might not enhance the anxiety experienced and hence not lead to a better emotional processing or more effective treatment.

Furthermore, it should be noted that failure rates were different for the CAVE- vs. HMD-condition, but this difference was not significant ($\chi2(1) = 1.6$, $P = 0.21$). Perhaps, for less severe acrophobic patients, who have trouble experiencing presence by means of an HMD, VRET in the CAVE can be a more effective option. Based on clinical experience though, the majority of clients with acrophobia can feel present in a height virtual environment using an HMD (e.g. Emmelkamp, Bruynzeel, Drost & van der Mast, 2001; Emmelkamp et al., 2002).

The results of the present study are in line with the two studies published earlier (Emmelkamp, Bruynzeel, Drost & van der Mast, 2001; Emmelkamp et al., 2002). In the Emmelkamp et al. study (2002) the same treatment protocol was used when comparing VRET using HMD to exposure in vivo. VRET was found to be as effective as exposure in vivo (Emmelkamp et al., 2002). As to the cost-effectiveness, HMD virtual reality treatment is much cheaper than VRET using a CAVE or the current golden standard exposure in vivo. HMD's are more compatible, much cheaper and easier to use in the therapist's office. The practical use of an HMD is much easier and treatment effectiveness is as good as with the CAVE or treatment outside the therapist's office. The real drawback though is that VR does not elicit anxiety in a substantial number of patients (10 of 35). This is a concern for the validity of the VR treatment in question.

In future research, larger amounts of subjects should be used and more sessions should be given before firm conclusions about VRET's effectiveness on fear of heights and its clinical relevance can be drawn. A BAT was used in order to investigate generalisation to the real world. This assessment, however, might be improved upon in future studies by adding SUD-ratings.

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