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Virtual reality treatment versus exposure in vivo: a comparative evaluation in acrophobia

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Abstract

The aim of the present study was to evaluate the effectiveness of low-budget virtual reality (VR) exposure versus exposure in vivo in a between-group design in 33 patients suffering from acrophobia. The virtual environments used in treatment were exactly copied from the real environments used in the exposure in vivo program. VR exposure was found to be as effective as exposure in vivo on anxiety and avoidance as measured with the Acrophobia Questionnaire (AQ), the Attitude Towards Heights Questionnaire (ATHQ) and the Behavioral Avoidance Test (BAT). Results were maintained up to six months follow-up.

The present study shows that VR exposure can be effective with relatively cheap hardware and software on stand-alone computers currently on the market. Further studies into the effectiveness of VR exposure are recommended in other clinical groups as agoraphobics and social phobics and studies in which VR exposure is compared with more emerging virtual worlds as presented in CAVE-type systems. © 2002 Elsevier Science Ltd. All rights reserved.

Keywords: Virtual reality; Exposure in vivo; Behaviour therapy; Acrophobia; Treatment outcome

1. Introduction

Virtual reality (VR) integrates real-time computer graphics, body tracking devices, visual displays, and other sensory inputs to immerse individuals in a computer-generated virtual environment. There is now some evidence that exposure can be conducted using VR technology. VR exposure has several advantages over exposure in vivo. The treatment can be conducted in the

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therapist office rather than that therapist and patient have to go outside to do the exposure exercises in real phobic situations and hence treatment may be more cost-effective than therapist-assisted exposure in vivo. Further, VR treatment can also be applied on patients who are too anxious to undergo real-life exposure in vivo.

A few case studies have been reported demonstrating the effectiveness of exposure provided by VR. Such case studies have been reported on fear of flying (North, North & Coble, 1997; Rothbaum, Hodges, Watson, Kessler, & Opdyke, 1996), acrophobia (Rothbaum et al., 1995a), claustrophobia (Botella et al., 1998), spider phobia (Carlin, Hofman, & Weghorst, 1997) and agoraphobia (Coble, North, & North, 1995). To date, two controlled studies have been reported. In a study on college students with fear of heights seven weekly sessions of VR exposure, conducted with a rather expensive laboratories computer, was found to be more effective than no-treatment control (Rothbaum et al., 1995b). Emmelkamp, Bruynzeel, Drost, and van der Mast (2001) evaluated the effectiveness of two sessions of low-budget VR versus two sessions of exposure in vivo in a within group design in individuals suffering from acrophobia. VR exposure was found to be at least as effective as exposure in vivo on anxiety and avoidance. The results of the Emmelkamp et al. (2002) study show that VR exposure can be effective with relatively cheap hardware and software on stand-alone computers currently on the market. This suggests that VR exposure will come within reach of the ordinary practitioner within the next few years.

In the Emmelkamp et al. (2002) study all patients received VR exposure as first treatment. We did not counterbalance both treatments because we expected a ceiling effect after two sessions of exposure in vivo (e.g. Emmelkamp & Felten, 1985), leaving insufficient room for further improvement with VR exposure. Unexpectedly, this is exactly what happened with VR exposure in the Emmelkamp et al. (submitted) study: VR exposure as first treatment was already so effective that a ceiling effect occurred thus diminishing the potential effects of exposure in vivo. Therefore, there was a clear need to replicate the findings in a between-group design.

The aim of the present study was to compare the effectiveness of exposure in vivo versus VR exposure in a between-group design with acrophobic patients. In order to enhance the comparability of exposure environments, locations, which were used in the exposure in vivo program, were exactly reproduced in virtual worlds that were used in VR exposure. Further, until now the evaluation of the effects of VR exposure has been restricted to self-report. In the present study, we also included a Behavioral Avoidance Test (BAT) in order to examine whether the effects of VR exposure generalise to real-life situations. Finally, the long-term effects of VR exposure have not yet been reported. Therefore, in the present study a follow-up was held six months after treatment, in order to investigate the long-term results of treatment.

2. Method

2.1. Design

Patients who fulfilled the research diagnostic criteria were randomly assigned to either exposure in vivo or VR exposure. After an intake session, patients received a pre-test followed by either three sessions of VR exposure or three sessions of exposure in vivo. A week after the last treatment session the post-test was held. Sessions in both treatment conditions lasted approximately

1 h and were held weekly. In the VR exposure condition, there was a break of a few minutes halfway each session in order to prevent motion sickness. Approximately six months after the post-test a follow-up was conducted.

2.2. *Subjects*

Patients were individuals suffering of acrophobia as their main complaint, who referred themselves for treatment after announcements in the national media, offering psychological treatment for acrophobia. To be included in the study, patients had to fulfil the DSM-IV criteria of acrophobia, acrophobia had to be the main problem, and patients had to be unable to complete the BAT. Of the 51 individuals, two were not included in the study, since one person did not have acrophobia as main complaint and one person had severe heart problems. Further of the 49 patients who fulfilled the criteria, five patients completed the BAT. These patients were excluded and treated outside the experimental trial. Six patients declined the treatment offered, and five patients dropped out during the study for different reasons. One did not find the treatment useful; two patients wore glasses that were stronger than -3.5 so VR exposure could not take place. With the last two patients treatment sessions could not be planned because of work changes or holidays. The remaining 33 subjects (15 females, 18 males) signed the informed consent and completed the treatment; the mean age was 43.97 years ($SD = 9.34$). The mean duration of their acrophobia was 31.49 years ($SD = 11.27$), thus showing that the acrophobia was chronic in most cases. Of the 33 patients who completed treatment, 29 (13 females, 16 males) were willing to co-operate in the follow-up.

2.3. *Treatment*

VR exposure was provided in a dark laboratory room at the Department of Clinical Psychology of the University of Amsterdam. The virtual worlds were generated using an ordinary Pentium Pro 233 MHz computer with 64 Mb RAM, 4 Gb harddisk, 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 visualisation 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. Tracking was done with Ascension Flock of Birds. To give the individual an enhanced feeling of height, a railing the user could hold on to surrounded the patient.

During the first session of VR exposure patients were acquainted with the VR by watching a virtual reality environment for a few minutes. Then patients were exposed to three different virtual environments which had been especially created for this project: (1) a mall in Amsterdam (Magna Plaza), existing of four floors with escalators and balustrades; (2) a fire escape in the centre of Amsterdam (height: approximately 50 feet; and (3) a roof garden at top of a university building (height: approximately 65 feet), with a view on the Magna Plaza building and a street. VR exposure was gradual and the therapist gave verbal guidance and encouragement. Patients were continuously instructed to look over the railing to ground level. Patients had to rate their anxiety level (subjective units of discomfort — SUDS) on regular times during the VR exposure exercises on a 0–10 scale. When the anxiety was diminished the therapist introduced the patient to a more

difficult exercise in the virtual environment. Patients were first exposed to the mall, secondly to the fire escape and at last to the roof garden. Depending on the anxiety of the patient and the time it took for the anxiety to attenuate patients were exposed to one, two or three virtual environments. The therapist, who handled the program by means of the keyboard of a personal computer and a joystick, controlled the VR exposure. Patients could look around freely and walk around on 1 m². The actual world seen by the patient was displayed to the therapist on a monitor.

Treatment activities during the *exposure in vivo* condition were held in the same three locations ((1) Magna Plaza; (2) the fire escape; and (3) the roof garden of the University building) as used with patients in the VR treatment. In Magna Plaza patients had to use the escalators, if necessary first accompanied by the therapist, later alone. Further they had to walk around at each floor, while looking down over the balustrades at ground level. At the fire escape patients had to climb the stairs to reach the landings, going near the edge of a landing and looking down at ground level. At the roof garden of the University building exposure exercises involved walking and looking down at ground level. All patients started in the first exposure in vivo session in Magna Plaza, followed by the fire escape and the roof garden in the following sessions. Depending on the degree of anxiety and the speed of habituation one, two or three locations were visited. Exposure was gradual and the therapist gave verbal guidance and encouragement. If necessary, the therapist accompanied the patient but he/she tried to withdraw his/her assistance as soon as possible. Patients had to rate their anxiety level on regular times during the exposure exercises on a 0–10 scale (SUDS). When the anxiety was diminished the therapist encouraged the patient to do a more difficult exercise.

All exposure tasks were performed during the sessions. Neither in the VR reality exposure condition, nor in the exposure in vivo condition were patients encouraged to do exposure exercises outside the therapy sessions.

Two advanced clinical psychology students (A.H. and S.V.) and one clinical psychologist (M.K.) who were supervised by the senior author conducted treatments. The therapists had followed an advanced course in behaviour therapy before they were admitted to the therapist team.

3. Assessment

Structured Clinical Interview for DSM-IV axis I disorders (SCID-I; Firtst, Spitzer, Gibbon, & Williams, 1996). To enable a formal diagnosis of acrophobia, patients were screened with the section anxiety disorders of the SCID-I. Furthermore patients had to complete the *Symptom Checklist (SCL-90; Derogatis, 1997)*, to check for other psychopathology.

The following questionnaires were completed at pre-test, post-test, and follow-up.

Acrophobia Questionnaire (AQ; Cohen, 1977). This questionnaire has two subscales: anxiety (range 0–120; Cronbach alpha.80) and avoidance (range 0–60; Cronbach alpha.70).

Attitude Towards Heights Questionnaire (ATHQ; Abelson & Curtis, 1989) which contains six questions assessing the attitude towards heights (range 0–60; Cronbach alpha.81).

A Behavioral Avoidance Test (BAT). At pre-test and post-test a BAT was conducted. Patients were requested to climb as high as they could without feeling anxious on a broad stairs (height:

Table 1
Means and standard deviations in parentheses of the dependent variables

Condition ^a	Pre-test		Post-test		Follow-up	
	In vivo (<i>n</i> =16)	VR (<i>n</i> =17)	In vivo (<i>n</i> =16)	VR (<i>n</i> =17)	In vivo (<i>n</i> =13)	VR (<i>n</i> =16)
BAT	12.12 (4.18)	11.42 (4.22)	17.52 (6.08)	16.83 (7.03)	–	–
AQ-anxiety	59.06 (17.12)	57.12 (12.18)	42.19 (17.14)	36.12 (20.56)	40.69 (17.03)	36.25 (19.12)
AQ-avoidance	15.38 (4.83)	14.00 (4.36)	9.44 (4.27)	8.53 (6.10)	9.88 (5.52)	8.53 (4.94)
ATHQ	43.50 (8.58)	45.94 (8.27)	34.25 (10.66)	31.18 (14.00)	33.15 (9.88)	33.13 (13.82)

^a Exception for BAT in vivo *n* =15 and VR *n* =16 (pre- and post-, no follow-up data).

approximately 38 feet) with railings. They were instructed to look continuously at ground level. If they became anxious they had to stay there for 1 min longer.

4. Results

Means and standard deviations are presented in Table 1. The data were analysed with MANOVA for repeated measures. The multivariate analysis (presented in Table 2) showed a significant time effect ($F(6) = 10.1, p < 0.000$). However, neither the condition effect ($F(3) = 0.541, p = 0.65$), nor the interaction condition \times time ($F(6) = 1.129, p = 0.38$) was significant. Paired *t*-tests are presented in Table 3. The *t*-tests revealed a highly significant time effect between pre-test and post-test on all dependent variables: AQ-anxiety, AQ-avoidance, ATHQ and BAT. On none of these variables was a significant difference between post-test and follow-up. Thus, improvements occurred between pre-test and post-test and were maintained up to six months follow-up. Between-group differences were further analysed with analysis of covariance, using

Table 2
Results of MANOVA for repeated measures, pre-, post- and follow-up (AQ-anxiety, AQ-avoidance and ATHQ, *n* =29)

Measures		<i>F</i>	df	<i>p</i>
<i>Multivariate</i>				
Overall	Time-effect	10.1	6	<0.000
	Condition-effect	0.541	3	<0.65
	Time \times condition	1.129	6	<0.378

Table 3

Paired *t*-tests for AQ-avoidance, AQ-anxiety, ATHQ and BAT, pre–post (*n* =33, except for BAT *n* =31)

Pair	Pre-test versus post-test			Post-test versus follow-up		
	<i>t</i>	df	<i>p</i> <	<i>t</i>	df	<i>p</i>
BAT (pre–post)	–6.926	30	0.000			
AQ-anxiety	5.761	32	0.000	0.942	28	<0.354
AQ-avoidance	5.684	32	0.000	–0.084	28	<0.933
ATHQ	6.074	32	0.000	–0.153	28	<0.879

the pre-test as co-variate and are presented in Table 4. Neither at the post-test, nor at follow-up was there a significant difference between the two conditions on any of the dependent variables.

5. Discussion

This is the first study in acrophobia in which the effects of VR exposure were compared with the golden standard of treatment for specific phobias (exposure in vivo) in a between-group design. VR exposure was found to be as effective as exposure in vivo on anxiety and avoidance as measured with the AQ and on ATHQ. The positive results of only three sessions of VR with formally diagnosed acrophobics in the present study support the earlier findings of Rothbaum et al. (1995b), who found seven sessions of VR exposure more effective than no-treatment control in college students with fear of heights and Emmelkamp et al. (2002), who found VR exposure at least as effective as exposure in vivo in a within group design in subject with fear of height from the community. In previous studies into VR exposure, the VR worlds were not identical to the situations used in real-life exposure. In this study, patients in the VR exposure condition were exposed to exactly the same three situations as were used with patients in the exposure in vivo conditions. Further, in contrast to previous studies, a BAT was added in the present study. Results revealed that improvement was not restricted to self-report. VR exposure led to the same improvement on the BAT as exposure in vivo, thus showing that results of VR exposure were not restricted to self-report, but also led to a reduction of actual avoidance behaviour. Further, the follow-up data revealed that patients were able to maintain their gains up to half year after treatment. It

Table 4

Univariate analysis of covariance on the dependent measures at post-test and follow-up, using the pre-test as co-variate

	Post			Follow-up		
	<i>F</i>	df	<i>p</i>	<i>F</i>	df	<i>p</i>
AQ-anxiety	0.675	1	<0.418	0.021	1	<0.886
AQ-avoidance	0.054	1	<0.818	0.199	1	<0.659
ATHQ	1.486	1	<0.232	0.003	1	<0.955
BAT	0.007	1	<0.936	–	–	–

should be noted, however, that a few patients received one session of exposure in vivo after the post-test, since we felt that this session could enhance their self-efficacy. A reanalysis of the results at follow-up, leaving out the patients who had received an additional exposure in vivo session after the post-test, revealed, that the results were still maintained at follow-up. Taken the results of these studies together, there is now considerable evidence that VR exposure is an effective treatment for patients with acrophobia.

It should be noted that we did not include a no-treatment control condition in the study, since we preferred to have sufficient statistical power to detect any between-group difference between VR exposure and exposure in vivo. However, given the chronic nature of the acrophobia (mean duration of 31.5 years) in our patients it is highly unlikely that the results are due to spontaneous recovery. Further, in the Rothbaum et al. (1995a,b) study in a less chronic student sample with fear of heights, VR exposure was found to be much more effective than no-treatment.

Given the positive effects of VR in patients with acrophobia, one may wonder whether treatment by VR exposure might also be effective in more disabling anxiety disorders like agoraphobia and social phobia. Given the idiosyncratic nature of these phobias and the variety of anxiety inducing stimuli involved, the development and clinical evaluation of VR exposure programs for these phobic disorders will be a challenge for the near future. Further, there is a clear need to investigate the effectiveness of VR presentations in a CAVE-system, since it is assumed that presentation of VR worlds in a CAVE will be more emerging than is currently possible with the system used in the present study.

As to the process of VR exposure, SUDS data revealed that the results of VR exposure are best explained in terms of habituation. Given the idiosyncratic nature of VR exposure, i.e. the choice and the duration of specific exposure exercises were individually determined, statistical analyses of the SUDS data were precluded. Inspection of the SUDS data during VR exposure and exposure in vivo revealed that patients were basically experiencing the same reactions. Typically, both in exposure in vivo and in VR exposure anxiety would first increase and steadily decrease when confronted with a new phobic situation. The overall anxiety level experienced during VR exposure, however, was somewhat lower than the anxiety experienced during exposure in vivo.

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