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Effectiveness of virtual reality exposure in the treatment of arachnophobia using 3D games

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Abstract. Buying or creating a virtual reality (VR) software is very costly. A less expensive alternative could be to modify already existing 3D computer games. The goal of this study is to assess the effectiveness of *in virtuo* exposure in the treatment of arachnophobia using modified 3D games. Participants were 10 women and 1 man. Virtual worlds were created using the game editor of a 3D computer game (Half-Life^{TM}), modified to offer graduals hierarchies of fearful stimuli (spiders). Analyses revealed significant improvement between pre and post results on the behavioral avoidance test, the Spider Beliefs Questionnaire, and perceived self-efficacy. These promising results suggest that therapy using virtual reality exposure via a modified computer game is useful in the treatment of arachnophobia.

Keywords: Virtual reality, exposure, specific phobia, games

1. Introduction

Virtual reality (VR) is defined as an application that allows its user to travel and interact in real time with a computer-generated three-dimensional environment [1]. Using VR as a therapeutic tool in exposure to feared stimuli is a promising idea that has received already some empirical support. Conducting exposure in VR (*in virtuo* exposure) offers many advantages compared to *in vivo* exposure. VR environments can reduce the occurrence of unpredicted events during exposure such as weather conditions (e.g., for thunderstorms phobia), turbulence (e.g., for flying phobia) or broken elevators (e.g., for heights phobia or claustrophobia). It can also reproduce situations that would be difficult to recreate *in vivo* (e.g., thunderstorms). *In virtuo* exposure could also allow therapists to reduce avoidance during exposure, as the therapist can watch the client while he is in direct contact with the feared stimuli. The therapist can reproduce the situation as often as needed and adapt the hierarchy in a very personalized way. In the long term, VR therapy may be less costly and more confidential than *in vivo*, especially when *in vivo* exposure has to be conducted outside the therapist's office (e.g. fear of flying). In the case

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of animal fears, no hygiene care is necessary and the animals' behavior is always perfectly controllable. Finally, Garcia-Palacios and her team showed that *in virtuo* exposure is more enticing than *in vivo* [2]. In a study with 162 arachnophobics, they offered their patients the choice between *in vivo* exposure and *in virtuo* exposure. They found that 81% of their participants would prefer to choose *in virtuo* exposure instead of *in vivo*. Given the fact that only 15 to 20% of specific phobic people actually seek treatment, this study suggests the possibility that more people would seek VR treatment if it was available.

In virtuo exposure is effective, at least to some extent. For example, Carlin and his team treated a 37 years old woman suffering from severe and incapacitating arachnophobia with twelve one hour sessions of gradual *in virtuo* exposure over three months [3]. They used a head mounted display (HMD) to immerse the participants in the VR environment. Their VR environment was a virtual kitchen in which the client could grab a tarantula. To enhance the client's experience, they placed a furry toy under the participant's hand when she grabbed the tarantula, which added a sensorimotor aspect to the visual ones. After therapy, the participant's scores on different cognitive and behavioural measures were significantly reduced. She could even take a live tarantula in her hands and keep her anxiety to a tolerable level.

Given VR therapy's enormous potential, more controlled research has already been made to empirically support its effectiveness in phobia treatment. Two randomized control trials compared *in virtuo* exposure to *in vivo* exposure. Rothbaum and her team randomly assigned 45 flight phobics to three groups: *in virtuo* exposure, *in vivo* exposure and waiting list [4]. Their results showed that VR therapy is at least as efficient as traditional *in vivo* exposure and statistically superior to the waiting list. At the 12 months follow-up, patients (80% of the 30 participants assigned to treatments) had maintained their gains and 91% of the *in vivo* exposure group and 92% of the *in virtuo* exposure group had flown on a real airplane on their own initiative [5]. Emmelkamp and his team assigned 33 acrophobics to an *in virtuo* exposure or an *in vivo* exposure groups [6]. Their results also confirm that *in virtuo* exposure leads to outcomes that are as effective as *in vivo*. For more extensive and critical reviews, see Bouchard, Côté and Richards [7] and Côté and Bouchard [8].

Current VR programs are very costly, as they can easily cost 10 000$US plus the cost of the hardware. In addition to being expensive, these environments are not readily adaptable to the needs of individual patients as it can be difficult to make small changes such as changing the color or size the phobogenic stimuli. Moreover these environments are usually compatible with only a limited range of display and input hardware. A less expensive alternative could be to modify already existing 3D computer games. The virtual environments created with these programs must usually be distributed for free, a licensing requirement imposed by the games' publishers in the End User License Agreement (copyright agreement). In some respects, despite their low cost, therapeutic virtual environments derived from games could be very useful. For example, they can be modified by users with little computing experience. The graphic quality of these virtual environments can be difficult to find in commercial therapeutic environments because the game engine are often very powerful and polygonal objects in the game-based environments are finely sculpted, textured, and rendered. However, their game-like feeling and the limits imposed by the 3D game editors softwares may sometimes prevent these environments to be useful therapeutic tools.

The goal of this preliminary study is to document the effectiveness of *in virtuo* exposure in the treatment of arachnophobia using VR environments created with the editor of a 3D game. Given the results of previous VR studies, it was hypothesized that a significant difference would be found on self-report cognitive and behavioral measures of spider phobia between pre and post-test.

2. Materials and methods

2.1. Participants

Patients were individuals suffering from arachnophobia as their main complaint. They were recruited through announcements in different medias in which psychological treatment was offered for arachnophobia. To be included in the study, participants had to be at least 18 years old, fulfill DSM-IV criteria for arachnophobia and be unable to go through the 10 steps of a Behavioral Avoidance Test (BAT). The 11 participants (10 females, 1 male) signed the informed consent and completed the treatment. The mean age was 30.73 ($SD = 9.08$). For all participants, the beginning of the phobia was reported to be in childhood.

2.2. Procedures

Patients were met for five weekly sessions of 90 minutes. During the first session, patients signed the consent form and were assessed using the *Structured Clinical Interview for DSM-IV* [9]. Following the diagnostic session, patients were given a traditional cognitive-behavioral model explaining their phobias and the exposure treatment. The therapists also introduced them to the VR equipment and participants had the chance to get immersed and navigate five minutes in a non-threatening (neutral) environment using the same equippment that was used for exposure. In the neutral environment, participants could walk freely outside and inside of a building where no spiders could be seen. This exercise allowed them to get more familiarized with the manipulation of the equipment and to get the skills to properly control their movements in the VR environment while they were not anxious.

The last three sessions were devoted to gradual exposure therapy using VR. In order to reduce the risks of eye-strain related to the head mounted display (HMD) unit, each exposure session was divided in three periods of 20 to 30 minutes, with a 5 minutes pause between each period. Every 5 minutes during exposure, participants were asked to rate on a 0-100 scale their subjective units of discomfort (SUDS), perceived level of presence, cybersickness and difficulty to confront their fear. The last fifteen minutes of the last session focused on relapse prevention. Participants received information about the importance of practicing their new skills, about adjusting their expectations towards their performance with spiders and about how to react in the occurence of a fearful reaction or emotion involving spiders. After each exposure session, participants had to wait for 15 minutes before leaving the clinic in order to assess the absence of side effects caused by the VR immersion.

After the intake session and the last exposure session, patients filled questionnaires and completed the Behavioral Avoidance Test (BAT). After each *in VR* exposure session, participants had to fill questionnaires assessing their feeling of presence and their cybersickness symptoms.

2.3. Assessment

The following questionnaires were completed at pre-test and post-test. The *Treatment Credibility Questionnaire* is an adaptation from Borkoveck and Nau and consists of five items [10]. Its test-retest stability is 0.90 ($p < 0.05$). The *Spider Beliefs Questionnaire* is made of 78 items that are divided in two sub-scales: beliefs about spiders and beliefs about the subject's own behaviors related to spiders [11]. The original version of this questionnaire has a Cronbach alpha of 0.94 for both subscales. It also has a test-retest fidelity of 0.68 ($p < 0.001$) for the beliefs towards spiders subscale and of 0.71 ($p < 0.001$) for the beliefs towards self in the presence of a spider subscale. The *Fear of Spiders Questionnaire* has 18 items that measure the severity of spider phobia and avoidance behaviors on a 7 degrees Likert scale [12]. The *Fear Survey Schedule-II* assesses 51 different stimuli that can cause fear [13]. Fear intensity is measured on a seven degree Likert scale (not at all scared = 0 to terrified = 7). All items were administered to participants. The *Perceived Self-Efficacy Questionnaire* was made of one question: "On a scale of 0 to 100, to what extent do you feel that you can face a situation where you are in the presence of one or many spider(s)?".

The *State-Trait Anxiety Inventory* is divided in two sub-scales (state anxiety and trait anxiety) of 20 items each, with various questions about how the participant feels the same day or in general [14]. The psychometric properties of this questionnaire have been empirically demonstrated [15]. The *Beck Depression Inventory* measures the intensity of a variety of depressive symptoms [16].

The *Immersion Tendencies Questionnaire* has thirty-four questions with a 7 degrees scale [17]. This questionnaire was developed to measure the susceptibility of a person to feel present in a virtual environment. The original version has a Cronbach alpha of 0.81. The French version has a Cronbach alpha of 0.78. The *Presence Questionnaire* is made of 32 questions that measure the feeling of presence in a virtual environment on an eight degrees scale [17]. The original version has a Cronbach alpha of .88. The French version, validated by the Laboratoire de Cyberpsychologie, has a Cronbach alpha of 0.84. The *Simulator Sickness Questionnaire* is frequently used in VR research [18]. It is made of 27 items using a 4 degrees scale to measure to what extent the participants feel cybersickness symptoms (i.e. nausea, eye fatigue, dizziness, etc.). The psychometric properties of this questionnaire have been empirically demonstrated.

After the first and last session, participants had to complete a behavioral avoidance test (BAT). This test consisted of different actions with a live domestic spider (*Pholocus phalangioides* or daddy-long-legs cellar spider, approximately two centimeters in diameter) divided in ten steps. Participants began the test sitting on a chair at three meters from the spider that was placed in an opaque plastic bowl on a table. Participants had to get up (step 0) and walk towards the spider until they stood next to the table (steps 1–6, each step representing walking a distance of 50 cm towards the table). They then had to look in the bowl for at least 5 seconds (step 7), take a pencil and touch the spider with it (step 8), take the spider at the tip of the pencil and take it out of the bowl (step 9) and finally touch the spider with their hands during at least 5 seconds (step 10). The participants were instructed to go through these steps until they felt that their anxiety level was too high to continue. There were also instructed not to push themselves beyond tolerance levels to test their capacities.

2.4. Materials

The virtual reality exposure was conducted with an IBM computer (*Pentium* III, 866 MHz, 128 Meg RAM), an *ATI Radeon* graphics card (64 Meg), a modified computer game (*Half Life*) using the 3D editor sold with the game, a head mounted display (resolution of 640x480; *I-Glass* i-O Display Systems), an *Intertrax* 2 tracker (3 degrees of freedom; InterSense) and a *Microsoft* joystick. Participant could move forward and backward in the VR environments using the buttons of the joystick. The therapists could see everything the patients saw through the computer screen. The sense of presence was enhanced with a black cloth that was placed around the head mounted display so participants could not see the rest of their body.

The virtual environment consisted in a 6 rooms bunker located in a basement.[1] All walls and floors were covered with grey cement, which reproduced a cold, unfinished basement atmosphere. This choice

[1]The VR environment is available to download for free at www.uqo.ca/cyberpsy.

was based on the limited options available with the 3D game editor and in order to make the participants believe they would be more likely to meet spiders. Participants started in a virtual room that reproduced the therapy room there were physically in. Once out in the hallway, they had the choice among 5 other rooms, all closed by a door: (1) a room with a table, a chair and a small black spider moving fast on the table and chair, (2) a room with a table on which there were two gray spiders with yellow stripes, medium-sized, one passive and the other following the moves of the participants, (3) a living room with many spiders of various sizes in many places, some following the participants or walking towards them, some passive, (4) a lunch room with spiders on the floor (participants could walk on them and kill them) and on the furniture and (5) a small room with a giant tarantula (the size of a dog) walking towards the participants when they were getting close.

2.5. Treatment

Treatment was delivered according to a treatment manual developed especially for this project.[2] Before the exposure began, patients were explained the gradual nature of the exercise and had access to a short descriptive list of each virtual room. They could then choose the room they wanted to begin with. The patients had to remain in one room until their anxiety (SUDS, rated on a 0–100 scale) was low enough to consider that the stimuli of that room were not eliciting anxiety anymore. Depending on each participant's level of anxiety, all the rooms were eventually visited or not, but each participant's progression rigorously respected the same standardized hierarchy.

The therapists' role was to guide and encourage the patients through their exposure exercises and enhance their level of presence by giving directions that were situation-oriented rather than technically-oriented. For example, instead of instructing patients to press the left button to move forward, therapists instructed them to walk to their left.

All the exposure was conducted in virtual environments. Patients were encouraged not to expose themselves to spiders at home as long as they had not completed the three *in virtuo* exposure therapy sessions.

Two advanced graduate clinical psychology students (S.C. & G.R.) and one undergraduate psychology student (J. St-J.) who were supervised by the senior author conducted treatments. The therapists had followed courses and personal training in cognitive-behavior therapy before they were allowed in the research team.

3. Results

3.1. Treatment effectiveness

Data were analyzed with repeated measures ANOVAs and are presented in Table 1. No significant difference was found between pre and post treatment on participants' treatment credibility. The average credibility was slightly lower at pre treatment than at post treatment, but not statistically significant. On arachnophobia measures, differences were found between pre and post treatment. Participants' beliefs score at the *Spider Beliefs Questionnaire* (SBQ) was significantly lower at post treatment and so was their behavior score. The same results were observed with the *Fear of Spiders Questionnaire* (FSQ). No significant difference was found on the *Fear survey schedule* (FSS) between pre and post treatment.

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[2] A French version of the manual is available at www.uqo.ca/cyberpsy.

Table 1
Assessment of the efficacy of a modified 3D games to treat arachnophobia. $N = 11$

Variables	Pre		Post		F	% of variance explained
	Mean	SD	Mean	SD		
Treatment credibility	41.2	8.24	45.55	4.03	3.99	0.29
BSQ beliefs	50.18	19.66	29.45	10.02	10.77**	0.51
BSQ behavior	50.81	17.79	22.55	10.05	24.06***	0.71
FSQ	83.27	7.99	40.09	17.67	52.82***	0.84
FSS	107.09	18.90	99.55	21.57	1.36	0.11
PSE	18.67	13.5	68.89	11.67	48.51***	0.86
BAT	2.55	2.11	5.73	2.24	115.57***	0.92
Immersion	69.22	11.57	78.22	18.19	7.55*	0.49

$^{*}p < 0.05$.
$^{**}p < 0.01$.
$^{***}p < 0.001$.
Note: the percentage of variance explained is based on the eta squared provided by SPSS.

Participants' perceived self-efficacy towards spiders (PSE) was significantly higher after treatment. Analyses on the behavioral avoidance test (BAT) revealed a significant difference between pre and post treatment. Before treatment, a majority of participants did not go beyond step 2 (standing at 200 cm of a spider in a plastic bowl). After treatment, a majority of participants reached step 6 (stand next to the plastic bowl) and 4 participants could touch the live spider with a pencil.

3.2. Virtual reality measures

The results of the analyses, revealed a significant difference between pre and post treatment on the *Immersion Tendencies Questionnaire*. Repeated measures ANOVAs were also made on measures that were taken through the exposure sessions. Significant differences were found on the *Presence questionnaire* ($F = 5,56,\ p < 0.5$, explaining 0.58% of the variance) but not on the Cybersickness questionnaire ($F = 2,96,\ p < 0.11$).

4. Discussion

The goal of this pilot study was to document the potential effectiveness of *in virtuo* exposure in the treatment of arachnophobia when VR environments are developed using editor of 3D games. It was hypothesized that a significant difference would be found on self-report cognitive and behavioral measures of spider phobia between pre and post-test.

Analyses revealed many differences between pre-test and post-test scores. On arachnophobia questionnaires, participants' scores significantly decreased. On the behavioral avoidance test (BAT), participants were able to go significantly further through the different steps after treatment. For example, many participants were able to touch the live spider with a pencil. Participants' perceived self-efficacy was found to be significantly higher after treatment.

Given the attractiveness of VR technology, one could wonder whether touching the virtual spider could increase treatment effectiveness. Especially since therapists usually encourage the patients to touch the spider during *in vivo* exposure and modeling exercises. Very few virtual environments currently in use for *in virtuo* exposure allow patients to touch the virtual stimuli. But SpiderWorld, designed by Hoffman and colleagues [22], allows patients to touch a furry toy spider while they are seeing their virtual hand touching the virtual spider in the HMD. Garcia-Palacios and her colleagues [19] used this virtual environment in a study where they randomly assigned 23 participants to either an *in virtuo* exposure treatment including tactile augmentation or to a waiting list. Participants could receive an unlimited number of sessions, but the average treatment length was four 60-minute sessions. In this study, two outcome measures could be compared with the current study: the *Fear of Spider Questionnaire* and a *BAT*. Their participants showed, on average, a reduction of 41% on their *FSQ* scores while the FSQ scores of those in the current study dropped by an average of 52%. On the post-treatment BAT, their participants were generally able to touch the container with the live tarantula while those in the current study were on average able to stand next to the container but not to touch it. The percentages of improvement on the BAT in the two studies are 57% in the Garcia-Palacios study and 55% in the current study, respectively. Since the two studies differ slightly in their treatment protocols and BAT, and the current study tested only a pilot version of the VR software, direct comparisons of improvement rates should be interpreted with caution. Nevertheless, the differences are not very important. Direct comparison of improvement on the BAT with independent studies using *in vivo* exposure is informative but should also be interpreted with caution. The average improvement on the BAT reported by participants receiving one session of individual therapist-directed *in vivo* exposure with modeling are 50% and 62% in studies by Öst [20,21]. However, in both studies, most participants were able to touch a spider at post-treatment. Another study using SpiderWorld also attempted to directly compare treatments with and without tactile augmentation [22]. Their results suggest an advantage of including tactile stimuli, but since only 8 clinically phobic subjects were allocated to one of three groups (control, with tactile augmentation and without tactile augmentation), the results are still too preliminary to draw firm conclusions.

No significant difference was found between pre and post treatment in participants' treatment credibility. The mean score being high at pre treatment, it can be assumed that therapists efficiently convinced the participants that VR therapy could help them with their fear of spiders. No significant difference was found between pre and post treatment on the *Fear Survey Schedule*, an instrument that measures fear towards many stimuli, not only spiders. This result may suggest that participants' other fears were not influenced by the treatment. Given the fact that exposure therapy was done in only three sessions and the post-test measure was done immediately after the last session, participants probably did not have the chance to generalize their therapeutic gains to other fears, if they had any.

Analyses revealed a significant difference between pre and post treatment on immersion tendencies. This suggests that exposure to VR therapy might have changed the participants' perception of their capacity to immerse themselves in an activity. Participants' sense of presence in the VR environments also increased significantly through the sessions. This suggests that practice with VR environments can increase the level of presence that is felt by participants. Scores of the cybersickness symptoms remained unchanged through the sessions.

Clinical observations during the treatment and comparisons with other outcome studies suggested that the VR environment could be significantly improved. For example, the spiders should be located in a more traditional environment (e.g., bedroom, kitchen), there should be more spiders and they should show more complex and diverse behaviors. A more powerful and flexible 3D engine than Half-Life would allow to construct a more detailed hierarchy, provide more opportunities to use the patient's imagination (e.g., there may be a spider under the bed) and help generalization, and in sum lead to a more effective treatment. Therefore, a new virtual environment has been created with a different 3D game editor (Max Payne) and is currently being tested [23].

As this study was done with relatively few participants and did not have a control condition, conclusions about VR effectiveness for spider phobia clearly need more scientific support. As the effectiveness of *in virtuo* exposure could be stronger on the BAT, more research is also needed to improve the treatment protocol used in this pilot study. However, the value of this study is its reliance on modified computer games to create the virtual environments. This reduces considerably software costs (90% less expensive) and makes environments easily accessible. Indeed, using the game engine and (legally) modifying the environments with game editors is a simpler task than developing an entire VR software. In addition, virtual reality therapy offers an interesting alternative to *in vivo* exposure, by making the feared stimuli completely controllable, adaptable, always available and secure.

These results, even if preliminary, are encouraging. They suggest that participants, even if treatment never implicated a real live spider, could be convinced enough to become anxious and go through exposure. Furthermore, they could transfer the skills they acquired in VR to the real world, being able to interact more with a "real" live spider and control their anxiety. In addition, their perceived self-efficacy after treatment being much higher, it could be concluded that they did not simply force themselves through the BAT steps but actually believed in their capacity to react efficiently with a real live spider.

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The virtual environment was created by Dominic Boulanger. It is available free on the lab's web site (http://www.uqo.ca/cyberpsy).

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