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Immersive 3D exposure-based treatment for spider fear: A randomized controlled trial

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ABSTRACT

Stereoscopic 3D gives the viewer the same shape, size, perspective and depth they would experience viewing the real world and could mimic the perceptual threat cues present in real life. This is the first study to investigate whether an immersive stereoscopic 3D video exposure-based treatment would be effective in reducing fear of spiders. Participants with a fear of spiders (N = 77) watched two psychoeducational videos with facts about spiders and phobias. They were then randomized to a treatment condition that watched a single session of a stereoscopic 3D immersive video exposure-based treatment (six 5-minute exposures) delivered through a virtual reality headset or a psychoeducation only control condition that watched a 30-minute neutral video (2D documentary) presented on a computer monitor. Assessments of spider fear (Fear of Spiders Questionnaire [FSQ], Behavioral Approach Task [BAT], & subjective ratings of fear) were completed pre- and post-treatment. Consistent with prediction, the stereoscopic 3D video condition outperformed the control condition in reducing fear of spiders showing a large between-group change effect size on the FSQ (Cohen's d = 0.85) and a medium between-group effect size on the BAT (Cohen's d = 0.47). This provides initial support for stereoscopic 3D video in treating phobias.

1. Introduction

An estimated 10–13% of the US population experiences a specific phobia at some point in their lives (Kessler, Berglund, Demler, Jin, & Merikangas, 2005; Magee, Eaton, Wittchen, McGonagle, & Kessler, 1996). Specific phobias can be very impairing with 34.2% of patients with reporting interference with their daily functioning (Magee et al., 1996). About 60–85% of those individuals with a specific phobia never seek treatment (Agras, Sylvester, & Oliveau, 1969; Boyd et al., 1990; Magee et al., 1996). Advances in technology are helping clinicians create novel treatment strategies for different anxiety disorders. Immersive 3D exposure-based treatments may help individuals with specific phobia confront their fears and treat their phobia in a more accessible and tolerable format.

Exposure-based interventions are one of the most effective strategies for treating a large range of anxiety disorders including social anxiety disorder (Powers, Sigmarsson, & Emmelkamp, 2008), panic disorder (Mitte, 2005), specific phobias (Wolitzky-Taylor, Horowitz, Powers, & Telch, 2008), posttraumatic stress disorder (Powers, Halpern, Ferenschak, Gillihan, & Foa, 2010), and obsessive-compulsive disorder (Olatunji, Davis, Powers, & Smits, 2013). However, there is room for improvement as exposure therapy, despite being effective for the majority patients, still has significant non-response rates (Barlow, Gorman, Shear, & Woods, 2000; Blanco et al., 2010; Hofmann & Smits, 2008; Simpson et al., 2013).

Exposure therapy is based on fear extinction principles (Davis, Ressler, Rothbaum, & Richardson, 2006). Therefore, strategies that can enhance the acquisition and retrieval of fear extinction memories should facilitate the outcome of exposure therapy. Over the past few decades, research with rodents has helped delineate the core neural

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systems and mechanisms involved in the encoding and retrieval of fear extinction. This research has given rise to augmentative strategies for exposure therapy (Anderson & Insel, 2006).

For either logistical or safety reasons it is not always possible to have patients directly face the object or situation they are afraid of in treatment. In those cases, it is necessary to find a representational stimulus that can elicit sufficient feelings of fear. For example, a patient could watch videos that feature the feared object. However, traditional 2D videos lack the visual cues of depth and motion that would be present if the patient encountered the stimuli in real life. These 3D cues are important in threat perception and their absence in exposure therapy could have an impact on treatment outcomes. In one previous study, researchers found a greater response in the amygdala to unpleasant stimuli presented in 3D than in 2D (Dores et al., 2014). This could have important implications on exposure therapy since previous research shows that greater amygdala activation during extinction can result in greater fear reduction (Flores, Herry, Maldonado, & Berrendero, 2017; Phelps, Delgado, Nearing, & Ledoux, 2004). Other studies found that looming stimuli (fear cues moving toward the participant) enhance threat perception and activation of the fear network in primates and in humans (Coker-appiah, White, Clanton, Martin, & Blair, 2014; Mobbs et al., 2010; Schiff, Caviness, & Gibson, 1962; Vagnoni, Lourenco, & Longo, 2012), which is also important for extinction of fear (Foa & Kozak, 1986; Herry et al., 2010). Therefore, one aim of the current study is to pilot test the use of immersive 3D looming stimuli for fear reduction. Next, we discuss recent advances in technology that make such stimuli possible.

The recent availability of low cost access to virtual reality (VR) in the consumer sector (e.g. Samsung Gear VR, Oculus Rift, HTC Vive) makes large-scale dissemination of virtual reality exposure-based treatment (VREbT) a reality. Also, recent advances in the simple creation of VR exposure stimuli make development of disorder-specific programs possible. However, while VREbT has shown promise in research (Powers & Emmelkamp, 2008), studies have shown that many users complain that the computer-generated VR stimuli looks unrealistic, eccentric, and too much like a video game (Kwon, Powell, & Chalmers, 2013). Virtual reality environments are traditionally created by programmers using computer-generated imagery (CGI; Garcia-Palacios, Hoffman, Carlin, Furness, & Botella, 2002; Miloff et al., 2016). While CGI can be used to make intricate virtual environments, unless there is a team of expert digital artists, the virtual stimulus may end up looking rudimentary and exhibit a number of graphical glitches, which could prove distracting in therapy. Furthermore, CGI often suffers from the uncanny valley effect: the tendency of CGI representations of people to be viewed as unsettling as the representations become more lifelike. In addition, the many current CGI VR packages are expensive and only available for limited number of fear domains. For example, the gold standard current VR setups can costs up to approximately $30,000.

Stereoscopic 3D video overcomes these limitations of CGI by using real footage rather than simulations to appear more realistic and to be cheaper to produce. 3D videos can be less flexible than CGI and generally do not allow as much virtual interaction with feared stimuli as certain CGI based exposure therapy platforms. Additionally, the 3D stimuli available for use in an exposure hierarchy is limited a priori by what has been filmed. Despite these disadvantages, stereoscopic 3D video has the capacity to give the viewer the same shape, size, perspective and depth they would experience in the real world. This occurs when the physical Field of View (FOV) of a viewed image is the same FOV that the camera recorded.

There are no trials to these authors' knowledge testing an immersive stereoscopic 3D video exposure-based treatment for reducing spider fear. Therefore, in the current study we randomized 77 participants with spider fear to an immersive stereoscopic 3D video exposure-based treatment and psychoeducation condition or a psychoeducation only condition and assessed spider fear at pre- and post-treatment. We predicted that the immersive 3D exposure-based treatment plus psychoeducation condition would outperform the psychoeducation control condition on behavioral and self-reported spider fear measures. We also predicted that participants would rate the stereoscopic 3D video as more immersive relative to the 2D control video condition.

2. Method

2.1. Participants

Participants were undergraduate students at The University of Texas at Austin enrolled in an introductory psychology class. They were recruited through a departmental pool and received course credit for their participation. All students in the departmental pool (N = 1,644) completed the Fear of Spiders Questionnaire (Szymanski & O'Donohue, 1995) as part of a departmental prescreen for research studies. Students scoring one standard deviation above the mean (i.e. a score of 59 or greater; n = 350) were invited to participate in the study. Interested students (n = 102) attended an in-person study visit for further assessment. They were invited to participate if they met the following additional eligibility criteria: (1) between the ages of 18 and 65; (2) unable to physically interact with a live tarantula prior to treatment during the behavioral approach task (BAT); and (3) not currently (or in the last 3 months) receiving exposure-based treatment for arachnophobia. Participants were excluded if they reported: (1) a history of strabismus ("crossed eyes" or "wandering eyes"), amblyopia (lazy eye), or any other impairment that causes difficulty seeing depth or 3D; (2) a diagnosis of far sightedness, astigmatism, or having difficulty reading small writing or fine print at a close distance, and being unwilling or unable to wear contact lenses (nearsighted participants were eligible to participate as the exposure video played on the Oculus Rift was close to the participants' eyes); or (3) a previous allergic reaction to a spider bite.

Of the 102 students invited to participate, 23 were excluded from the study because they were able to physically interact with a live tarantula during the screening BAT. One participant was excluded due to experiencing dizziness during the Oculus Rift trial video. Another participant was excluded due to experiencing a past allergic reaction to a spider bite.

Seventy-seven participants met all inclusion criteria and completed all study procedures. The mean age was 19.27 years (SD = 1.13; range 18–23). Participants were primarily female (87.01%; n = 67). The mean FSQ score of all participants prior to enrollment was 76.79 (SD = 13.5; range 59–108). See Fig. 1 CONSORT Diagram.

2.2. Materials/equipment/apparatus

2.2.1. Stereoscopic presentation of exposure stimuli

The immersive 3D exposure-based treatment was administered using an unmodified Oculus Rift DK1 virtual reality headset. The Oculus Rift DK1 uses a 3° of freedom head tracker (3-DOF), has a 1280 × 800 resolution (640 × 800 per eye), a refresh rate of 60 Hz and a Field of View 110°. More recent versions of the Oculus Rift have improved specs. For this study we did not utilize the Oculus Rift for its head tracking but for its ability to present immersive stereoscopic 3D. The Oculus Rift uses two different spherical lenses to induce a sense of stereoscopic 3D.

Ortho-stereoscopy refers to stereoscopic capture that is a full-sized true-to-scale reproduction of the original object in all three dimensions and that appears at the same distance from the eye as the object. In theory perfect true ortho-stereoscopy creates a 3D image, which mirrors the real world with completely accurate depth, size and perspective. However in practice true perfect ortho-sterescopic footage is incredibly hard to achieve just because it is not only in how the subject is recorded but also it depends on how the material is displayed. For example, in order to achieve true ortho-stereoscopy for a given moment the viewer would have to be positioned at the exact same distance away from the

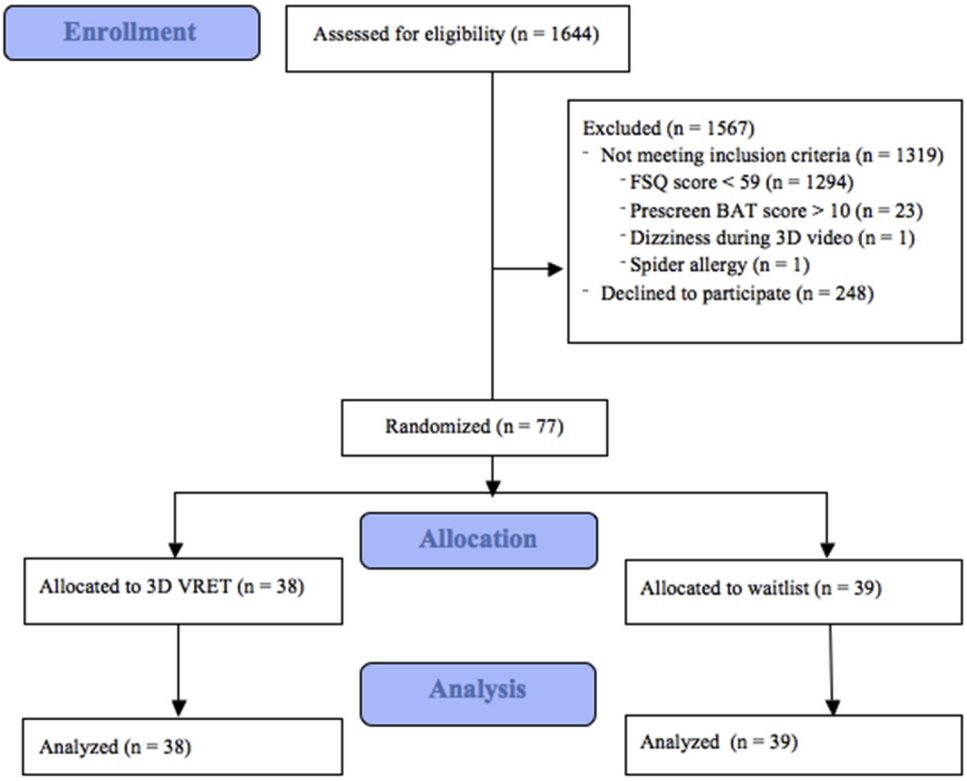

Fig. 1. A consort diagram of participant flow.

screen as the cameras were positioned when the recording happened and the viewing screen would have to have a field of view that is identical to the focal length that the recording cameras used which places very strict limitations on camera. Due to logistical limitations of filming a live moving tarantula and in order to get certain shots of the spider looming towards the camera, true ortho-stereoscopy was not achieved on all the footage. However, we were still able to shoot in an ortho-stereoscopic style in order to mirror real depth representation as closely as possible.

To create these 3D videos, the UT 3D Department shot videos of a live Chilean rose hair tarantula using a stereoscopic 3D dual camera rig, which simultaneously shoots footage with two cameras positioned apart from each other in a way that mimics the natural pupillary distance between the right and left eyes. To create a sense of 3D depth, the footage of the right and left cameras is then projected on the two different lenses of the Oculus Rift, creating a sense of depth to the viewer through retinal disparity.

2.2.2. Software

The stereoscopic videos were played using the program Stereoscopic Player. Stereoscopic Player is commercial video player for stereoscopic video footage (http://www.3dtv.at/Shop/Index_en.aspx).

2.3. Measures

2.3.1. Fear of spiders questionnaire

The Fear of Spiders Questionnaire (FSQ; Szymanski & O'Donohue, 1995) was used as a measure of the efficacy of the immersive 3D exposure-based treatment. The FSQ is an 18-item self-report measure for assessing level of spider phobia. Participants rate their agreement with statements about fear and avoidance regarding spiders, such as "spiders are one of my worst fears," on a 7-point Likert-type scale (0 = strongly disagree to 6 = strongly agree). Total scores range from 0 to 108 with a cutoff of 15 or above reflecting at least a midlevel fear of spiders. The FSQ shows good test–retest consistency, excellent split-half reliability and internal consistency, construct validity in its ability to discriminate phobics from non-phobics, and convergent validity with a BAT (r = 0.65, $p <$ 0.001; O'Donohue & Szymanski, 1993; Muris & Merckelbach, 1996; Szymanski & O'Donohue, 1995).

2.3.2. Behavioral approach task (BAT)

A BAT was conducted prior to treatment for screening purposes to ensure sufficient fear of spiders beyond what is measured with the FSQ and after treatment as an outcome measure. The pre-treatment BAT also served as a baseline level of spider fear that, when compared to the post-treatment BAT, was used as an objective measure of clinical progress in overcoming arachnophobia.

The BAT was divided into 14 distinct steps (see Table 1) corresponding to sequentially closer contact with a spider. A large spider (Chilean rose hair tarantula; *Grammostola rosea)* was placed in a lidless transparent plastic container that was on a shelf against the wall of the study room. Four pieces of tape were placed one foot apart on the floor dividing the distance the participant would walk to approach the spider container in steps 1-4. Three pieces of tape were placed on the wall of the container marking where the participant's hand should be lowered for steps 6-8. Participants were told that the objective of the task was to complete all 14 steps, but that they could end the BAT at any time if they became too fearful. The BAT ended when all 14 steps were completed or if the participant did not proceed to the next step within 15 s. Participants were excluded from the study if they were able to physically interact with the spider during the pre-treatment BAT (i.e. completed step 11 or higher).

2.3.3. Subjective measures

Seven computer-presented sliding scales were used for the participant to rate (a) the highest level of fear felt (0 = no fear; 50 = moderate amount of fear; 100 = extreme fear), (b) the highest level of disgust felt (0 = no disgust; 50 = moderate amount of disgust; 100 = extreme disgust), (c) how realistically immersive the viewing experience was (0 = static **black** and **white** photograph; 50 = flat screen

Table 1
Behavioral approach test step specifications.

Score	Description
1	Began BAT and stood at line one-fifth of the distance to the container
2	Stood at line two-fifths of the distance to the container
3	Stood at line three-fifths of the distance to the container
4	Stood at line four-fifths of the distance to the container
5	Reached container and placed fingertips of one hand even with the top of the container
6	Lowered hand so that fingertips were one-quarter of the distance to the container floor
7	Lowered hand so that fingertips were two-quarters of the distance to the container floor
8	Lowered hand so that fingertips were three-quarters of the distance to the container floor
9	Touched the container floor with the tip of index finger
10	Placed palm of hand flat on the bottom of the container
	Participant removed hand and sat at a desk while research personnel picked up the spider
11	Placed the palm of one hand face down on the desk and had the spider, guided by research personnel, crawl across their hand
12	Placed the palm of one hand face up on the desk and had the spider, guided by research personnel, crawl across their hand
13	Held the spider in the palm of their hand for 10 seconds
14	Held the spider in the palm of their hand for 15 seconds

television; 100 = real life), (d) how well the participant engaged and confronted the spider (0 = extremely poorly; 100 = extremely well), (e) how dangerous the participant felt the spider was (0 = harmless; 100 = fatal), (f) how well participants thought they would do in terms of pushing ahead and completing steps during the BAT that seemed challenging (0 = extremely poorly; 100 = extremely well), and (g) the extent the participant tried to go beyond their limits during the BAT (0 = didn't try; 50 = tried a little; 100 = couldn't try any harder). The scales were explained orally to the participant prior to answering to ensure comprehension. Participants selected their rating by moving a sliding scale cursor with the computer mouse. In addition to being administered before and after the BAT, the subjective scales were also collected every five minutes during the immersive 3D exposure-based treatment and served as a treatment process measure of perceived fear, disgust, immersion, performance, and dangerousness of spider.

2.3.4. 3D vision questionnaire

The 3D Vision Questionnaire was developed by the authors of this study to assess the participant's previous experiences with 3D videos and if they had any vision impairments listed as eligibility exclusion criteria that would interfere with the experiment.

2.4. Procedures

The study was conducted in the virtual reality room in the Anxiety and Health Behaviors Lab at The University of Texas at Austin. The experiment was presented on a Dell Optiplex 7010 desktop with two standard monitors positioned side-by-side to allow participants to view the 3D video on the Oculus Rift headset using one monitor while research personnel could access the control panel on the second monitor. Study measures were administered and collected using Qualtrics [Computer software] (2017).

Students who scored above the inclusion cut-off score an online prescreen (FSQ ≥ 59) were invited to the lab for one in-person study visit lasting approximately two hours. Participants were individually tested and given the same general information regarding the experimental proceedings before signing an informed consent form. Following consent procedures, participants completed the FSQ, 3D Vision Questionnaire, and then were fitted to the Oculus Rift headset to ensure they were comfortable when watching the 3D videos. Some participants' eyelashes touched the lenses of the Oculus Rift headset during fitting. In this case, participants were instructed to remove the head straps and hold the headset up to their face with two hands during all subsequent study videos. Participants next watched a 2-minute trial 3D video of neutral content on the Oculus Rift headset to ensure they were able to view the 3D images and did not experience any significant discomfort from the video. After the trial video, research personnel orally described the subjective sliding scale measures to participants and checked for understanding.

Prior to completing the pre-treatment BAT, participants watched a 2D instructional video on a computer monitor describing the procedure for the 14-step BAT. The video featured a human modeling each approach step with a spider to help prevent confusion. Immediately following the video clip, research personnel restated the instructions of the BAT and verified that the participant understood it was not mandatory to complete all 14 steps of the BAT. Participants then answered the subjective measures to report how they felt while watching the BAT instructional video, as well as their anticipatory feelings about how they expected to feel while completing the BAT. Next, participants were instructed to face the wall adjacent to the door - across from the tank that would house the spider - while the researcher left to retrieve the spider. Participants were instructed to refrain from turning until the spider was in the tank and research personnel instructed the participant to do so.

Participants then completed the pre-treatment BAT and research personnel recorded the highest step completed. Research personnel then removed the spider from the room while participants completed the subjective sliding scale measures. Participants who scored an 11 or above on the pre-treatment BAT were thanked for their time and excluded from the study. Following the pre-treatment BAT, participants watched two consecutive 4-minute psychoeducational 2D videos on a computer monitor, one that dispelled common myths about spiders and one about how phobias are developed and maintained. Eligible participants were then randomized (by an electronic random number generator) into one of two conditions: immersive 3D exposure-based treatment group or a psychoeducation only control group. Randomization was stratified by gender.

2.4.1. Treatment

Prior to treatment, participants in the immersive 3D exposure-based treatment condition watched a short video explaining the basis of exposure therapy and how the immersive 3D exposure-based treatment sessions would take place during the study. Treatment consisted of viewing one 5-minute video, 6 times, in stereoscopic 3D with increasing intensity of spiders as it progressed. The video progressed through footage of:

1 A *Grammostola rosea* spider being held by a model.
2 The spider being positioned closer to the camera.
3 The spider being placed even closer and moving towards the camera.

Due to the 3D effect of the video, as the spider approached the camera, extremities of spiders tend to jump out as if coming directly

towards participants. In the latter portions of the video, the spider was also crawling towards the camera to produce a looming sensation.

Research personnel were seated next to participants during the virtual reality task in order to assist with the video and adjust the Oculus Rift if needed. However, experimenters were unable to view the participants' eye movements because the Oculus Rift covers the participants' eyes while the video is being viewed. Therefore, the experimenters could only instruct the participants to refrain from safety behaviors during the virtual reality task and could not ensure that behaviors related to eye movements were followed. Participants were told to engage as much as possible with the stimuli and to avoid safety behaviors, (such as closing their eyes, looking away, etc.), during the task. At the end of each 5-minute video, participants completed the subjective measures battery (i.e. highest level of fear 0–100, highest level of disgust 0–100, etc.). Research personnel administered the measures orally so that the Oculus Rift remained on the participant's head throughout the treatment session.

2.4.2. Psychoeducation control

In addition to the two initial psychoeducational videos, participants in the control condition watched a neutral 30-minute 2D documentary video about music genres that had no apparent emotional valence or relevance to fear of spiders. Psychoeducation control participants were given the opportunity to receive the immersive 3D exposure-based treatment after the one-week follow-up FSQ was completed.

2.4.3. Post-treatment

All participants then watched the BAT instructional video and completed the post-treatment BAT. Following the BAT, participants recorded their subjective measures. The participants were fully debriefed and thanked for their participation.

2.4.4. Post-treatment 2

The FSQ contains some items with language that are unlikely to be sensitive to change moments after pre-treatment assessment and treatment (e.g., "currently, I am sometimes on the look out for spiders"; "currently, I sometimes think about getting bit by a spider"; "spiders are one of my worst fears.") Due to the nature of the FSQ items and phrasing, the FSQ post-treatment measure was collected one week later.

3. Results

3.1. Preliminary analyses

Independent-samples *t*-tests showed no significant differences between the treatment condition and control condition at pretreatment in demographic and subjective measures: age, $t(75) = 1.76$, $p > .05$, anticipated fear during BAT, $t(75) = -0.39$, $p > .05$, anticipated disgust during BAT, $t(75) = -0.39$, $p > .05$, expected danger during BAT, $t(75) = -1.13$, $p > .05$, how well participants thought they would do in terms of pushing ahead and completing steps during the BAT that seemed challenging, $t(75) = -1.46$, $p > .05$, the extent the participant tried to go beyond their limits during the BAT, $t(75) = 0.17$, $p > .05$, and anticipated BAT steps completed, $t(75) = 0.14$, $p > .05$. No differences were found between the two groups on the FSQ, $t(75) = 0.15$, $p > .05$, or the pre-treatment BAT, $t(75) = -0.72$, $p > .05$.

3.2. Outcome analyses

To test the effectiveness of the immersive 3D exposure-based treatment we conducted a 2 (group) x 2 (time-pre vs. post-treatment) repeated measures ANOVA for each outcome measure. Means and standard deviations at the pre- and post-test assessments are shown in Table 2.

Table 2
Mean and standard deviations for the outcome measures at pre- and post-treatment (note: 3D VRET = 3D virtual reality exposure therapy; WL = Waitlist; BAT = behavioral approach test; FSQ = Fear of Spiders Questionnaire).

Variable	3D VRET (n = 38)		WL (n = 39)	
	M	*SD*	*M*	*SD*
BAT score				
Pre-treatment	6.97	2.71	7.41	2.65
Post-treatment	10.74	2.61	9.97	2.58
BAT fear				
Pre-treatment	79.40	18.77	70.44	17.63
Post-treatment	47.03	26.89	60.00	24.28
Anticipatory fear				
Pre-treatment	78.39	17.44	79.77	13.23
Post-treatment	49.53	21.41	63.05	16.54
FSQ score				
Pre-treatment	76.37	16.77	75.85	13.43
Post-treatment 2	38.79	19.44	56.92	24.12

3.2.1. FSQ score

The mixed-model ANOVA showed a significant Time effect, $F(1,75) = 172.6$, $p < .001$, a significant Group effect, $F(1, 75) = 5.6$, $p < .05$, and a significant Group by Time interaction, $F(1,75) = 18.82$, $p < .001$. The interaction indicates that the immersive 3D exposure-based treatment group improved significantly more on the FSQ than the control group when comparing pre-treatment scores to scores at post-treatment 2 (see Fig. 2). A relative change effect size comparison showed a Cohen's $d = 0.85$ (SE = 0.24, 95% CI: 0.384–1.32) indicating a large effect for the immersive 3D exposure-based treatment relative to the control condition on the FSQ. Results for the FSQ showed that at posttreatment, 21% of the treatment group had achieved clinically significant improvement compared to 8% of the control group (FSQ < 24; Müller, Kull, Wilhelm, & Michael, 2011; Rinck & Becker, 2007).

3.2.2. BAT score

The mixed-model ANOVA showed a significant Time effect, $F(1,75) = 189.81$, $p < .001$, no significant Group effect, $F(1, 75) = 0.09$, $p > .05$, and a significant Group by Time interaction, $F(1,75) = 6.82$, $p < .05$. The interaction indicates that the groups differed in amount of improvement on the BAT (see Fig. 3). As displayed in Table 2, the immersive 3D exposure-based treatment group improved significantly more on the BAT than the control group. A relative change effect size comparison showed a Cohen's $d = 0.47$ (SE = 0.23, 95% CI: 0.014–.92) indicating a medium effect for the immersive 3D exposure-based treatment relative to the control condition.

3.2.3. Fear during the BAT

The mixed-model ANOVA showed a significant Time effect, $F(1,75) = 55.92$, $p < .001$, no significant Group effect, $F(1, 75) = 0.23$, $p > .05$, and a significant Group by Time interaction, $F(1,75) = 14.68$, $p < .001$. The interaction indicates that the immersive 3D exposure-based treatment group showed a significantly greater reduction in self-reported fear ratings during the BAT than the control group.

3.2.4. Anticipatory fear rating prior to the BAT

The mixed-model ANOVA showed a significant Time effect, $F(1,75) = 130.01$, $p < .001$, a significant Group effect, $F(1, 75) = 4.75$, $p < .05$, and a significant Group by Time interaction, $F(1,75) = 9.24$, $p < .01$. The interaction indicates that the immersive 3D exposure-based treatment group showed a significantly greater reduction in self-reported anticipatory fear ratings prior to the post-treatment BAT than the control group.

3.2.5. Immersion

An independent-samples *t*-test indicated that participants in the

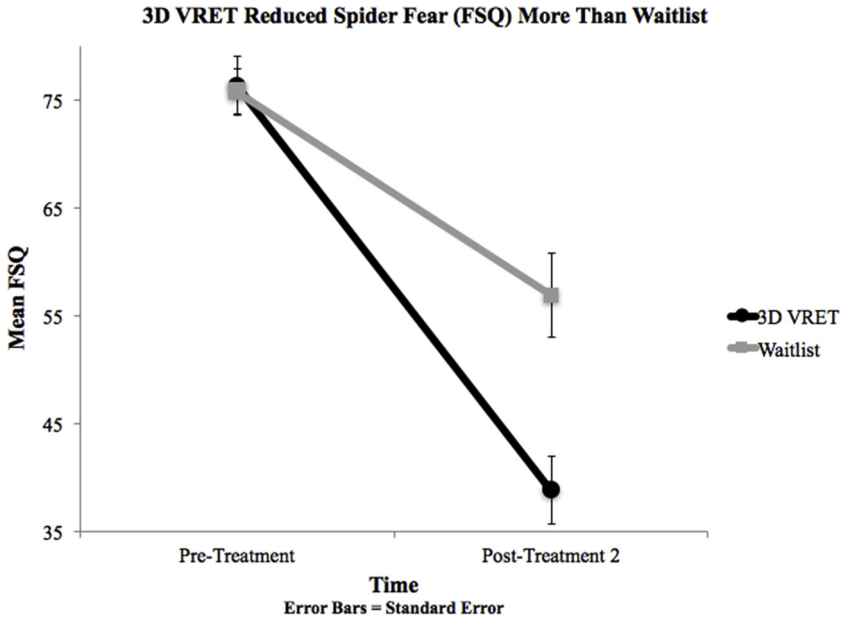

Fig. 2. Participants in the 3D VRET condition had greater reduction in self-reported spider fear (FSQ) than participants in the waitlist condition at post-treatment 2.

treatment condition (M = 77.79, SD = 13.42) rated the immersive 3D exposure-based treatment video significantly more immersive than participants in the control condition (M = 55.93, SD = 19.72) rated the 2D control video, $t(75) = 5.68$, $p < .001$.

4. Discussion

This is the first controlled study to demonstrate the effectiveness in using stereoscopic 3D live action clips in the treatment of fear of spiders. Thirty minutes of immersive 3D exposure-based treatment significantly reduced participants' fears of spiders as measured by self-report scales and behavioral approach tasks compared to a control condition, with a large between-group change effect size on the FSQ (Cohen's d = 0.85) and a medium between-group effect size on the BAT (Cohen's d = 0.47). This means that the mean improvement of the treatment group was at the 80% percentile of the mean of control participants on the FSQ, and 67% on the BAT (Cohen, 1988).

The 3D video clips were able to sufficiently elicit feelings of fear during treatment. As participants became desensitized to these video clips their ratings of fear decreased, which generalized to reduced fear and avoidance towards a real spider.

Participants regarded the immersive 3D exposure-based treatment very positively and reported high feelings of immersion during treatment. This suggests that it may not be necessary to have an interactive VR environment to create an immersive exposure therapy experience. Notably, none of the participants who started the immersive 3D exposure-based treatment dropped out, indicating that the treatment was an acceptable medium of treatment delivery in this sample.

The results support our prediction that 3D video exposure-based treatment is effective for specific phobia. Countless studies have shown

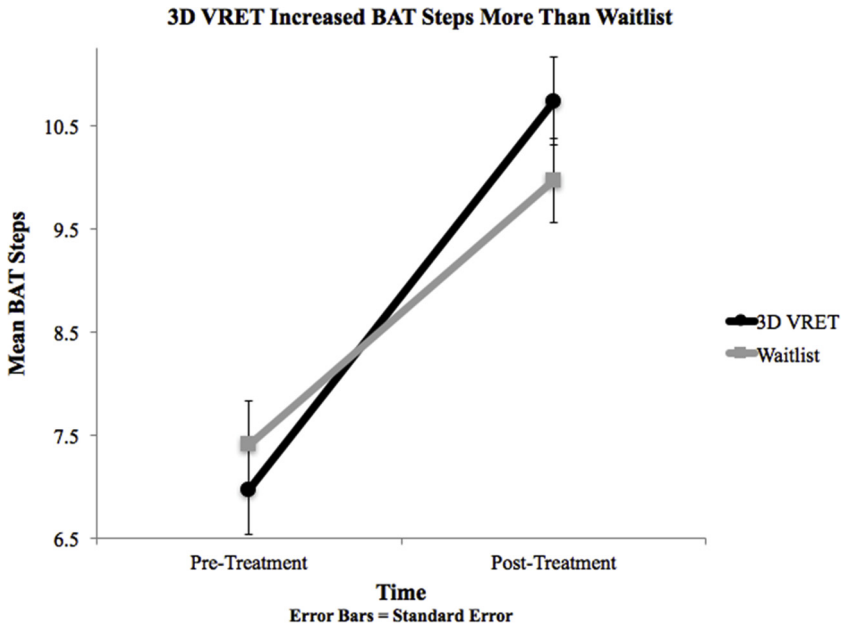

Fig. 3. Participants in the 3D VRET condition had greater increase in steps taken during a behavioral approach test (BAT) than participants in the waitlist condition at post-treatment.

in-vivo exposure therapy to be a highly effective treatment, but immersive 3D exposure-based treatment has several advantages. First, it is logistically easier to host a digital library of clips that represent different phobias and fears than it is to house real stimuli in an office. Next, there are many fears that would be unsafe for in vivo exposure therapy which are easy to simulate with 3D video. Additionally, 3D video can afford greater control over the stimuli than is possible during in vivo exposure. For example, by wearing the 3D headset, patients can repeatedly experience a spider crawling directly toward their face.

Stereoscopic 3D live action video also has a number of advantages over CGI VR platforms. Stereoscopic 3D live actions videos do not suffer from the uncanny valley effects present in CGI. Additionally, it is easier and more cost effective to create novel 3D video stimuli by filming more live action footage as opposed to conventional VR where creating new stimuli requires extensive programing and graphic design.

This study has several limitations. First, our study recruited spider fearful participants instead of individuals with clinically diagnosed spider phobia. On one hand, this perhaps suggests that the effectiveness of the immersive 3D exposure-based treatment could generalize to the large number of people who have subclinical fears that they would like to confront. A clinical sample could show an even greater response to the treatment given they have "further to go." In addition, this treatment may be a more attractive/tolerable option for people with more severe fears who are unable/unwilling to engage with traditional exposure therapy. Alternatively, greater severity of baseline fear in a clinical sample could slow treatment gains. Future studies could test the treatment with clinically diagnosed phobic participants (e.g. endorsing significant life interference) in order to more precisely test its efficacy for the specific targeted group. Also, the generalizability of the findings is limited given that our sample was primarily female and age-restricted due to recruiting from the university's departmental subject pool. Future studies should use a more diverse sample. An additional limitation in this study is that self-reported fear of spiders was only assessed one week after the experiment. Future studies would benefit from monitoring changes in spider fear over a longer follow-up period in order to determine if the treatment effects found in this study persist or if there is an return of fear. Another limitation is that this study used a 3D vision Questionnaire to assess if the participants had any visions problems, which would interfere with their ability to comfortably watch the 3D videos. Future studies would benefit using specialized device designed to test participants' stereoscopic vision such as Randot Stereotest. Also, eye tracking was not available for this study. Eye tracking could confirm what participant where actually attending to during the exposure and rule out the use of safety behaviors (looking away from the spider). Finally, a significant limitation on this study is that it compared the immersive 3D exposure-based treatment to a psychoeducational control condition rather than another medium for exposure-based treatment. While this study showed that immersive 3D exposure-based treatment was more effective than control for spider fear, future studies should compare immersive 3D exposure-based treatment to 2D video-based exposure in order to more thoroughly examine incremental utility of 3D visual cues on exposure therapy outcomes. Additionally future studies should compare 3D exposure-based treatments to traditional spider fear treatment (i.e., in-person exposure to spiders) to assess whether there is an advantage in effectiveness or acceptability to either medium of treatment delivery.

Overall, our findings suggest that stereoscopic 3D video is an effective tool in exposure therapy. The ability of stereoscopic 3D to simulate the cues of depth and motion found in normal vision gives the medium greater potential to simulate the experience of encountering fears in the real world. Its simplicity as a medium and relatively low cost could attract a larger number of individuals with specific phobia to therapy.

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