Pergamon

S0005-7967(96)00085-X

Behav. Res. Ther. Vol. 35, No. 2, pp. 153–158, 1997

0005-7967/97 $17.00 + 0.00

SHORTER COMMUNICATIONS

Virtual reality and tactile augmentation in the treatment of spider phobia: a case report

ALBERT S. CARLIN,[1] HUNTER G. HOFFMAN[2,3,*] and SUZANNE WEGHORST[3]

[1]Psychiatry and Behavioral Sciences, University of Washington, [2]Department of Psychology, University of Washington and [3]Human Interface Technology Laboratory, University of Washington, P.O. Box 352142, Seattle, WA 98195-2142, U.S.A.

(Received 26 August 1996)

Summary—This is the first case report to demonstrate the efficacy of immersive computer-generated virtual reality (VR) and mixed reality (touching real objects which patients also saw in VR) for the treatment of spider phobia. The subject was a 37-yr-old female with severe and incapacitating fear of spiders. Twelve weekly 1-hr sessions were conducted over a 3-month period. Outcome was assessed on measures of anxiety, avoidance, and changes in behavior toward real spiders. VR graded exposure therapy was successful for reducing fear of spiders, providing converging evidence for a growing literature showing the effectiveness of VR as a new medium for exposure therapy. Copyright © 1997 Elsevier Science Ltd

INTRODUCTION

Spider phobia is characterized by persistent fear of spiders, an immediate anxiety response upon exposure to spiders, and avoidance of spiders. Fear of phobic proportions can interfere with the patient's normal social routines, activities and interpersonal relationships, and can produce marked distress about having the fear. The person typically recognizes that his or her fear is excessive or unreasonable (American Psychiatric Association, 1994). Desensitization, a treatment based on gradually and systematically exposing the phobic person to the feared object or situation, and calming them, has proved to be an effective treatment for a wide range of phobias, including fear of spiders (e.g. Marks & Gelder, 1965).

Recent researchers have found the application of virtual reality to be effective in the desensitization of fear of heights (Rothbaum, Hodges, Kooper, Opdyke, Williford & North, 1995), and fear of flying† (Hodges, Rothbaum, Watson, Kessler & Opdyke, 1996; Rothbaum, Hodges, Watson, Kessler & Opdyke, 1996) suggesting that a VR-based desensitization program may also be effective for the treatment of other phobias such as spider phobia. One potential advantage of VR over other techniques lies in the greater ability of the patient or therapist to control the feared stimulus. Unlike a real spider, virtual spiders obey commands, can be placed in various positions and orientations by patient or therapist, and can be touched without danger. VR allows the experimenter to control how frightening the spiders appear.

Immersive virtual reality (VR) is a phenomenon in which an illusory reality is created in the mind of the computer user. VR often involves computer simulations of real objects in near-real time. Observers typically wear helmets containing two small video monitors (one for each eye) attached to a high-speed computer. The image presented to one eye is slightly offset from the image presented to the other eye. In the real world, this offset provides a depth cue known as parallax. In the virtual world, artificial parallax helps give participants the illusion that they are in a 3-D space interacting with 3-D objects. With the aid of position tracking devices, the computer can monitor a person's physical movements and adjust the images (and sounds) presented accordingly. Due in part to these life-like changes in visual imagery in response to their own actions, *Ss* often report a feeling that they are "in a different place" when navigating the computer-simulated world. This subjective experience of presence in the virtual environment (e.g. Barfield & Weghorst, 1993) is thought to be the essence of virtual reality (Laurel, 1995). In the present study, the place the patient visits is "Spider World", a virtual kitchen and house that is home to two virtual spiders, a large furry brown one, and a smaller black widow with a white 3-D spiderweb.

In order for VR therapy to be successful, desensitization must generalize to real spiders. Generally, the more similar a simulated environment is to the real environment, the better the transfer of training to the real world (Thorndike, 1931). Like most virtual worlds from the mid-1990s, our virtual environments were somewhat cartoon-like and required some suspension of disbelief on the part of the user. In the present study, tactile augmentation (Hoffman *et al.*, 1996) was introduced in an attempt to maximize the level of presence achieved and to maximize the transfer of training from VR to the real world. Tactile augmentation is a form of mixed reality where *Ss* feel position-tracked real objects (with their hand) that correspond to virtual objects they see in the immersive virtual environment.

*Author for correspondence at Human Interface Technology Laboratory.

†Their study effectively combined treatment of anxiety management techniques (AMT) and VR exposure so the contribution of VR to success is suggested not definitive.

METHOD

Subject history

Mary Muffet is a 37-yr-old single woman who has been phobic of spiders for the past 20 yr. As a teen, she briefly kept a pet tarantula in a terrarium. One day, when she opened the terrarium lid, the tarantula jumped for the first time, and jumped surprisingly high. As a result of this frightening experience, she gave it away. But she denies a direct link between that event and the onset of her phobia. When she was 17 yr-old her parents were out of town and two friends slept over. The friends grew panicky when they encountered some spiders in Ms Muffet's house. Ms Muffet thought her friends were over-reacting, and she calmly carried the spiders outdoors. A few days later after her parents returned, she encountered a spider in the house and displayed the same panicky behavior her friends modeled for her a few days before. Whether these events influenced the eventual onset of her severe phobia is unknown. The etiology of spider phobia is not well understood (Kirkby, Menzies, Daniels & Smith, 1995).

At the time she entered into treatment, any encounter with a spider or a spider web resulted in panic, waves of anxiety, weeping, shame about her 'out of control' behavior, and sadness about how limited her life was. Ms Muffet's efforts to limit her contact with spiders had severely constrained her life. She chose to work a 'graveyard' shift of her job to reduce contact with spiders. Prior to going to work, she thoroughly washed and vacuumed her car every day, to wash off any spiders. She frequently fumigated her vehicle with pesticides, and also left cigarettes burning in the ashtray with the windows closed, after hearing from a friend that spiders avoid smoke. Ms Muffet wore special 'spider gloves' while driving, in case it was necessary to sweep spider webs out of the car window on the way to work.

Prior to going to sleep she scanned her room and placed folded towels in the door jam of her bedroom door to keep spiders out. All bedroom windows were sealed with duct tape each night. The patient was hypervigilant, searching for spiders wherever she went, and avoiding walkways where she might encounter a spider. After washing her clothes, she ironed each piece of clothing, and placed each individual piece of clothing inside a sealed plastic bag, to make sure it remained free of spiders. One day, despite all her precautions, she found a large spider on her couch, and had a very intense reaction to it. She was becoming hesitant to leave her house at all because of the chance of encountering spiders. Her sister urged her to seek treatment for her phobia.

Because of the obsessive–compulsive quality to her difficulties, a pharmacological consultation was requested that resulted in a recommendation that she undergo a trial of Luvox.* Although the patient was amenable to a pharmacological approach she viewed it as a last resort and stated a preference for a behavioral approach.

Initial treatment involved discussions about the nature of the anxiety response. She judged herself to be engaging in irrational "out-of-control, crazy behavior" when she encountered spiders. The patient was encouraged to learn to tolerate and accept her anxiety as a conditioned response to spider stimuli that could be eventually extinguished. She accepted this reconceptualization which helped reduce her catastrophic interpretations of the anxiety she experienced upon encountering a spider.

Early treatment began with exposure to field guide photographs of spiders. This created strong anxiety and was barely tolerable. After several sessions the photographs became more tolerable and eventually created little discomfort. Treatment then proceeded to models of spiders, initially a flat plastic Halloween decoration was anxiety provoking, but within three sessions of exposure, Ms Muffet hung the plastic spider object from her truck's rear view mirror as an ornament. One of her colleagues gave her a gift of a pair of silver spider earrings, which she could wear but found anxiety provoking to closely examine. At the same time she was successfully encouraged to broaden the range of rooms she was willing to enter and occupy at home.

While these preliminary exposures may have helped prepare the patient for the VR exposure therapy that followed, the patient was still extremely phobic. She still had most of the symptoms she had displayed when she initiated therapy. The patient suggested that VR therapy might be more effective. All preliminary treatments were discontinued before beginning the VR exposures and all measures reported below address the efficacy of VR exposure therapy only.

Measures

Six fear of spider questions were chosen from a set of 18 questions (Szymanski & O'Donohue, 1995) to help assess the efficacy of VR treatment. Previous researchers have found the full questionnaire to have excellent split half reliability and internal consistency, good test–retest consistency, convergent validity due to its highly significant correlations with a behavioral avoidance test ($r = 0.65$, $P < 0.001$), and construct validity in its ability to discriminate phobics from nonphobics as measured by a behavioral avoidance test (O'Donohue & Szymanski, 1993; Szymanski & O'Donohue, 1995). These questions are designed to measure the patient's anxiety about spiders. Both before and after VR exposure treatment the patient responded to the following items.

(1) I would do anything to avoid a spider.
(2) If I came across a spider now, I would leave the room.
(3) If I saw a spider now, I would ask someone to kill it.
(4) If I saw a spider now, I would be afraid of it.
(5) If I saw a spider now, I would feel panicky.
(6) I would feel very nervous if I saw a spider now.

Unlike O'Donohue and Szymanski (1993) who counted positive responses, we asked the patient to rate each item on a 1 to 7 scale. (1 = does not apply to me, 7 = very much applies to me). The patient also completed a short absorption questionnaire (Tellegen & Atkinson, 1974). This measure is comprised of 34 true–false questions designed to assess the *S*'s tendency to become lost in a daydream or movie, (e.g. "When I listen to music, I can get so caught up in it that I don't notice anything else"). To serve as a standard of comparison, the fear of spider questions and the absorption survey were also administered to 280 undergraduates in an introductory psychology course at the University of Washington.

*Her obsessive thoughts and compulsive behaviors associated with the object of her fear suggest that Ms Muffet warranted the diagnosis of obsessive–compulsive disorder instead of a 'simple' phobia.

Four presence questions adapted from Slater, Usoh and Steed (1994), and from Hoffman, Hullfish and Houston (1995) were used to assess how 'present' the *S* felt in the virtual world. Hendrix and Barfield (1995) describe several studies showing the reliability of a similar subjective measure of presence. In our study, *S*s were asked to rate on a scale ranging from 1 through 7:

(1) How real did the virtual world seem to you? (1 = about as real as an imagined world, 7 = indistinguishable from the real world).
(2) To what extent were there times when you felt that the virtual world became 'reality' for you, and you almost forgot about the real world outside? (1 = at no time, 7 = almost all the time).
(3) Did the virtual world seem more like something you saw, or some place you visited? (1 = something I saw, 7 = some place I visited).
(4) In the virtual world, I felt more like... (1 = I was standing in the laboratory wearing a helmet, 7 = I was in the virtual room).

Apparatus

The VR system consisted of a Division ProVision 100, coupled with a Division dVisor® head mounted display with the following field of view characteristics: 40 degrees vertical, 105 degrees horizontal combined across two eyes, and 40-degree horizontal overlap. A 3-D mouse allowed *S*s to move forward in the virtual kitchen by pushing a button. A Polhemus 6D sensor attached to a fingerless bicycle glove (right hand) was used to control the position of the cyberhand,* and a second sensor controlled the position of the virtual spider. During tactile augmentation sessions, the latter was attached to a furry toy spider.

Treatment

Over a period of 3 months, two of the authors (ASC, HGH) conducted 12 weekly sessions approximately 50 min long. Each session consisted of five, 5-min trials with a 2 or 3-min break between trials. The breaks were incorporated to reduce fatigue and reduce the likelihood of 'simulator sickness', a form of motion sickness sometimes evoked by VR, which wasn't a problem for our patient. The *S* was encouraged to interact with the spider in each situation long enough for her anxiety to decrease to a level where she felt ready to progress to a more frightening situation. She progressed at her own pace. Her anxiety level was assessed once a minute during exposure on a scale of 1 (no anxiety) to 10 (panic-level anxiety). The researchers were able to view what the *S* was doing in VR by looking at a video monitor, and were able to interact with the patient appropriately. The therapist's comments were roughly similar to what would be expected for conventional *in vivo* exposure. The patient was sometimes encouraged to pick up the spider and/or web with her cyberhand and place it in orientations that were most anxiety provoking. Other times, the experimenter controlled the spider's movements by physically moving a position sensor, by entering new position coordinates into the keyboard, or by using preprogrammed spider behaviors (unexpected jumps, etc). A large brown virtual spider with photograph-quality 'texture-mapped' fur was used. A smaller black spider and an associated 3-D web were also introduced.

Spiders were placed in a cupboard with a web, made to jump unpredictably upon being touched, made to climb or drop in incremental jumps between the ceiling and the virtual kitchen floor, and they were touched, held and manipulated by the *S*. The real-world counterpart of the brown spider, used for tactile augmentation, consisted of a palm-sized replica of a Guyana bird-eating tarantula. Coincidentally, this reminded the patient of her jumping pet spider mentioned earlier. Fur from the tail of a stuffed toy dog was glued onto the body of the toy spider. After 1 month (four, 50-min VR therapy sessions), tactile cues were first introduced into the virtual world using the tactile augmentation technique (Hoffman *et al.*, 1996). As the patient reached out with her cyberhand to explore the virtual object, her real hand explored the toy spider attached to a polhemus position sensor. The virtual spider now felt furry, and had weight ('cyberheft') and any movement of the toy spider caused a similar movement of the virtual spider.

RESULTS AND DISCUSSION

Activities in Spider World kept the patient's anxiety level relatively high throughout therapy. The highest rating for each 5-min session was averaged for each day of therapy. The mean of these 12 daily anxiety scores was 7.9 on a scale from 1 to 10 where 10 = panic-level anxiety. Especially during the first month, the *S* often experienced physical symptoms concommitant with her high anxiety ratings: dryness of the mouth, uncontrolled shaking of the hands and legs, and profuse sweating (often visible), and reports of being on the verge of tears.

Our dependent measure indicates significant progress. Pre to post-treatment changes in ratings of subjective anxiety in response to specific activities with VR spiders showed strong evidence of anxiety reduction after 3 months of VR therapy. For example, the level of anxiety provoked by the tactile augmentation spider initially elicited very high ratings (she tried to rate it as 15 on a scale from 1 to 10 where 10 = panic-level anxiety, even though aware that 10 was the highest possible rating). Her anxiety remained high for the next session of tactile augmentation therapy before finally beginning to decrease (i.e. before the patient began to evidence habituation to the mixed reality spider). The mixed reality spider initially evoked such a strong emotional reaction that as she held the spider by its artificial fur with trembling hand, the patient unintentionally shut her eyes to reduce the anxiety (she later realized), and still displayed all of the physical symptoms described above. In addition, she reported that she felt shaky several hours after she left the laboratory the night of her first mixed reality spider treatment. After approximately 2 more months of therapy, the mixed reality spider was no longer effective in evoking a strong emotional reaction; the same mixed-reality stimulus evoked a rating of only 3, and no physical symptoms. After each therapy session, the patient engaged in deep muscle relaxation prior to leaving the lab. (She used this during the sessions as well.)

Fear-of-spider ratings provide converging evidence for the overall efficacy of the therapy. Figure 1 shows the patient's total fear of spider rating (the sum of 6 ratings on a 7-point scale) relative to the distribution of such ratings for the undergraduate comparison group. Prior to treatment, only 1 undergraduate out of 280 had an equal or higher fear-of-

*We refer to the virtual representation of the subject's hand as a 'cyberhand'.

spiders rating than the patient. After 12 sessions of VR desensitization treatment, the patient's fear ratings dropped considerably. Twenty-nine percent of the 280 undergraduates tested (i.e. 80 students) now had equal or higher total fear-of-spider scores than the patient.

Although more difficult to quantify, perhaps the clearest indication of the efficacy of this treatment is the dramatic reduction in dysfunctional behavior after therapy. The patient became less vigilant of spiders, no longer engaged in any of the obsessive–compulsive rituals associated with avoiding spiders, and reports having much more free time available as a result. She now spends more time outdoors and has recently gone camping, something she was unable to do for the past 16 years because of her spider phobia.

The total of the absorption ratings was also calculated for each undergraduate and the patient. The patient's absorption score was in the upper 6% of the undergraduate distribution, suggesting that our patient had an unusual disposition to be captured by entrancing stimuli. Other factors contributing to the success of the treatment were the patient's very strong motivation and her associated self-initiated exposure to spiders *in vivo*. For example, she looked at a real spider she found in her kitchen at home for 20 min, and crushed another large, real spider with significant, but manageable anxiety, although not specifically instructed to do so. These self-initiated *in vivo* exposures probably played an important role in the transfer of training from VR to the real world. Rothbaum *et al.* (1995) report a similar tendency in their fear-of-heights study. Interestingly, experience in the real world may also transfer back into the virtual world. The patient was more easily frightened by virtual spiders during the third week of therapy, after having a frightening experience with a real spider earlier that week. This opens the question of whether some hybrid of real, virtual and mixed reality exposure treatments might be uniquely effective.

GENERAL DISCUSSION

The present study shows that treatment of spider phobia in VR (a form of training) successfully transferred to the real world. Our clinical patient's fear of real spiders was abated by exposure to virtual spiders. Systematic desensitization with VR graded exposure was effective in reducing reported anxiety, and avoidance of real spiders. These results converge with those of other researchers (e.g. Rothbaum *et al.*, 1995, 1996) in supporting the use of VR for treatment of clinical psychological disorders. The present study is the first use of immersive VR to treat spider phobia, and the most serious clinical case treated with immersive VR exposure therapy (as far as the authors are aware). Other published studies (e.g. Rothbaum *et al.*, 1995) found VR graded exposure to be effective in the treatment of experimental *S*s who rated themselves as fearful of heights, but who had not sought treatment prior to being recruited by the experimenter. Hodges *et al.* (1996) report a case study of a patient who sought treatment for fear of air travel so she could go on vacations with her family, and could take a new job requiring travel. Their *S* was probably not as incapacitated by her disorder, and according to the authors, the contribution of VR to her progress is unclear since another treatment was administered simultaneously. Our finding that VR treatment can be effective for such a serious and pervasive disorder is important. While there is good reason to be optimistic that treatments effective on non-clinical populations will also be effective on clinical populations, it is reassuring to demonstrate that generalization.

We introduced the first use of tactile cues in VR therapy. Being able to feel the virtual spider was very effective at eliciting a strong emotional response. Tactile augmentation leads to the formation of chimeric memories that are part real and part virtual (Hoffman, in preparation). This blurring of the boundary between real and unreal made possible with virtual and mixed reality likely helps the transfer of VR training to the real world.

As suggested by Rothbaum *et al.* (1995), future research should explore the use of VR for treatment of other psychological disorders (especially treatment of anxiety-related disorders). One limitation in case studies such as the present one is that they must be followed up with larger studies to insure generalizability of the findings.

Multi-participant VR will allow the clinician to take the form of an avatar who can interact with and speak to the patient *inside* the virtual environment via a microphone that feeds into the patient's helmet mounted display. This will

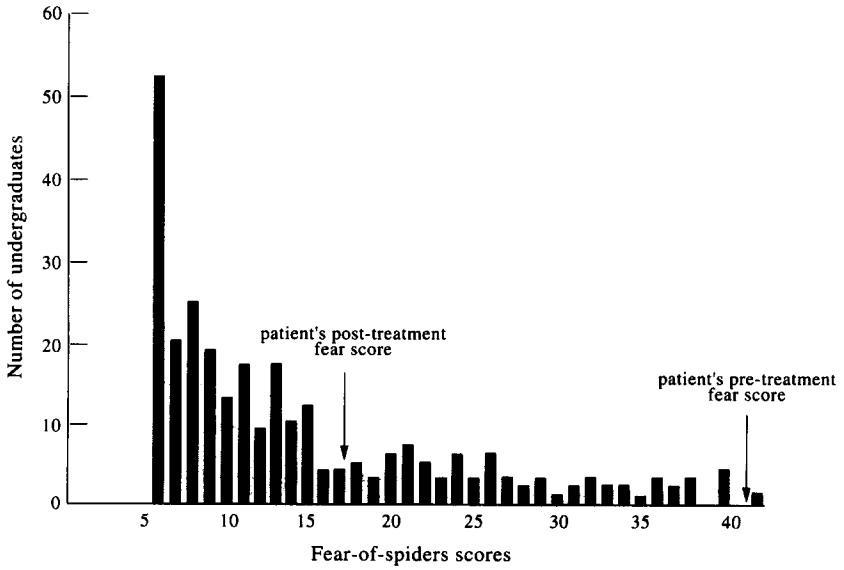

Fig. 1. Patient's fear-of-spiders scores compared to undergraduates.

likely increase *Ss*' sense of presence, which is thought to decrease as attention is distracted away from the virtual environment by conversations with people in the lab room (Winn, Hoffman & Osberg, 1995).

Our study also bears on the issue of whether the level of presence experienced by a patient in VR is related to the therapeutic success of VR therapy. Our patient experienced a moderate level of presence before the spider was introduced in the first session, and always gave the highest ratings possible on the presence questions thereafter (i.e. when exposed to the virtual spider). Hodges *et al.* (1995) argue that the experience of a high level of presence may be necessary for effective immersive VR therapy. Although not conclusive, our data is consistent with that claim. However recent research is using non-immersive 3-D shutter glasses to make computer animated spiders appear to hover between the patient and the 2-D computer screen (Goetestam, Hollup & Graawe, 1996; Hollup, 1996). This use of desktop non-immersive computer-animated stimuli does not make *Ss* feel present in a computer-simulated environment. Despite this fact, Hollup and colleagues have found the technique to be very effective for exposure treatment of spider phobia. Their data suggest that 'ego' presence is *not* a defining factor necessary for successful treatment of phobia with virtual spiders (at least using non-immersive equipment). Rather, object presence, or *Ss*' impression that the computer-animation spider is actually 'there' between the *S* and the computer screen, may contribute to successful treatment using their approach. Future collaborative research comparing the two techniques (immersive VR and 3-D shutter glasses) is planned. Another interesting issue for future research is whether the level of presence experienced can be predicted beforehand based on reported personality characteristics such as absorption. Tellegen and Atkinson (1974) described absorption as a receptivity to experiences of deep involvement, a heightened sense of reality of the object being attended, and a disregard for normally distracting events. We speculate that people with high absorption ratings will feel more present in virtual reality and will respond more favorably to VR treatment than people with low absorption ratings.

Researchers and artists are beginning to explore the use of emotion to evoke a strong sense of presence in VR. As entertainers move into the VR market, they will likely bring with them all the tricks of the movie trade (e.g. suspense, emotion-evoking music, etc.) to make the VR experience more effective. Future research should explore the use of these techniques in virtual therapy.

Acknowledgements—The authors would like to thank Scott Rousseau for computer modelling and texture-mapping the brown spider, and to Ari Hollander for generous save-the-day software programming (e.g. writing custom code to get one of the two cyberhands to change into a big brown spider, etc) and troubleshooting. Thanks to Jason Doctor for valuable comments, and to the US West VRRV project, AFOSR Grant No. F49620-93-1-0339, Division Inc, and the other HIT Lab consortium members for donating VR equipment and for generous support.

REFERENCES

American Psychiatric Association (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: American Psychiatric Association.

Barfield, W., & Weghorst, S. (1993). The sense of presence within virtual environments: A conceptual framework. In G. Salvendy & M. Smith (Eds.), *Human computer interaction: Hardware and software interfaces* (pp. 699–704). Amsterdam: Elsevier.

Goetestam, K. G., Hollup, S., & Graawe, R. W. (1996). *Virtual Reality in the treatment of spider phobia: An experimental controlled study*. Paper presented at the World Psychiatry Congress in Barcelona.

Hendrix, C., & Barfield, W. (March, 1995). Presence in virtual environments as a function of visual and auditory cues. *Proceedings of VRAIS '95*. Los Alamitos, CA: Research Triangle Park, NC. IEEE Computer Society Press.

Hodges, L. F., Rothbaum, B. O., Kooper, R., Opdyke, D., Meyer, T., de Graff, J. J., Williford, J. S., & North, M. (1995). Presence as the defining factor in a VR application. Georgia Institute of Technology, Graphics, Visualization, and Usability Center, Technical Report GIT-GVU-94-5.

Hodges, L. F., Rothbaum, B. O., Watson, B., Kessler, G. D., & Opdyke, D. (1996). *A virtual airplane for fear of flying therapy*. Paper presented at the meeting of the Virtual Reality Association International Symposium (VRAIS), Santa Clara, CA.

Hoffman, H. G. (in preparation). Virtual source monitoring accuracy for identifying the sources of chimeric memories.

Hoffman, H. G., Groen, J., Rousseau, S., Hollander, A., Winn, W., Wells, M., & Furness III, T. (1996). *Tactile augmentation: Enhancing presence in inclusive VR with tactile feedback from real objects*. Paper presented at the meeting of the American Psychological Society, San Francisco.

Hoffman, H. G., Hullfish, K. C., & Houston, S. (1995). *Virtual-reality monitoring*. Paper presented at the meeting of the Virtual Reality Association International Symposium (VRAIS), Research Triangle, NC.

Hollup, S. A. (1996). Virtual-reality therapy in the treatment of spider phobia. Master thesis, Department of Psychology, Norwegian University of Science and Technology, Trondheim, Norway.

Kirkby, K. C., Menzies, R. G., Daniels, B. A., & Smith, K. L. (1995). Aetiology of spider phobia: Classificatory differences between two origins instruments. *Behavior Research and Therapy, 8*, 955–958.

Laurel, B. (1995). Virtual Reality. *Scientific American, September*, 90.

Marks, I. M., & Gelder, M. G. (1965). A controlled retrospective study of behaviour therapy in phobic patients. *British Journal of Psychiatry, 111*, 571–573.

O'Donohue, W. T., & Szymanski, J. (1993). Mechanisms of change in cognitive therapy in a simple phobia: Logical analysis and empirical hypothesis testing. *Journal of Rational-Emotive and Cognitive Behavior Therapy, 11*, 207–222.

Rothbaum, B. O., Hodges, L. F., Kooper, R., Opdyke, D., Williford, J., & North, M. M. (1995). Effectiveness of virtual reality graded exposure in the treatment of acrophobia. *American Journal of Psychiatry, 152*, 626–628.

Rothbaum, B. O., Hodges, L. F., Watson, B. A., Kessler, G. D., & Opdyke, D. (1996). Virtual reality exposure therapy in the treatment of fear of flying: A case report. *Behavior Research and Therapy, 34*, 477–481.

Slater, M., Usoh, M., & Steed, A. (1994). Depth of presence in virtual environments. *Presence: Teleoperators and Virtual Environments, 3*, 130–144.

Szymanski, J., & O'Donohue, W. (1995). Fear of Spiders Questionnaire. *Journal of Behavioral Therapy and Experimental Psychiatry, 26*, 31–34.

Thorndike, E. L. (1931). *Human learning*. New York and London: The Century Co.

Tellegen, A., & Atkinson, G. (1974). Openness to absorbing and self-altering experiences ("absorption"), a trait related to hypnotic susceptibility. *Journal of Abnormal Psychology, 83,* 268–277.

Winn, W., Hoffman, H. G., & Osberg, K. (1995). *Semiotics and the design of objects, actions and interactions in virtual environments.* Paper presented at American Educational Research Association, San Francisco, CA. Also to be published in *International Journal of Educational Psychology.*