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The role of presence in virtual reality exposure therapy

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Abstract

A growing body of literature suggests that virtual reality is a successful tool for exposure therapy in the treatment of anxiety disorders. Virtual reality (VR) researchers posit the construct of presence, defined as the interpretation of an artificial stimulus as if it were real, to be a presumed factor that enables anxiety to be felt during virtual reality exposure therapy (VRE). However, a handful of empirical studies on the relation between presence and anxiety in VRE have yielded mixed findings. The current study tested the following hypotheses about the relation between presence and anxiety in VRE with a clinical sample of fearful flyers: (1) presence is related to in-session anxiety; (2) presence mediates the extent that pre-existing (pre-treatment) anxiety is experienced during exposure with VR; (3) presence is positively related to the amount of phobic elements included within the virtual environment; (4) presence is related to treatment outcome. Results supported presence as a factor that contributes to the experience of anxiety in the virtual environment as well as a relation between presence and the phobic elements, but did not support a relation between presence and treatment outcome. The study suggests that presence may be a necessary but insufficient requirement for successful VRE.

Keywords

Exposure therapy; Virtual reality; Specific phobia; Anxiety disorders

Recent reviews suggest that virtual reality exposure (VRE) is an effective treatment for anxiety disorders (Anderson, Jacobs, & Rothbaum, 2004; Krijn, Emmelkamp, Olafsson, & Biemond, 2004b). Virtual reality exposure uses a computer-generated environment to recreate a feared stimulus. The utility of virtual reality (VR) as a tool for exposure has rested on the assumption that virtual environments can elicit anxiety and provide the opportunity for habituation, a view which remains widespread today (Rothbaum, Hodges, Kooper, & Opdyke, 1995; Wiederhold & Wiederhold, 2005b). The construct of presence, defined as the interpretation of an artificial environment as if it were real (Lee, 2004), has been discussed as the mechanism by which VR may be an effective tool for exposure therapy (Wiederhold & Wiederhold, 2005a). Presumably, presence contributes to the amount of anxiety felt during an exposure to a feared virtual stimulus. Despite a widespread theoretical assumption, the empirical support for the relation of presence, anxiety, and treatment outcome in VRE is unclear. The present study intends to contribute to the conflicting findings of previous work by examining the role of presence in VRE.

A literature review revealed three empirical studies that have examined the relation between presence and anxiety. Regenbrecht, Schubert, and Friedmann (1998) examined whether or not a sense of presence was related to anxiety in a virtual environment simulating elevated

heights. Thirty-seven non-phobic participants were presented a virtual heights environment. The results did not support a bivariate relation between a self report measure of presence and anxiety. However, a more comprehensive multiple regression that included presence, trait anxiety, and avoidance behaviors as predictors of in-session anxiety showed that presence was significantly related to in-session anxiety, offering some support for the relation between presence and anxiety during exposure to a virtual environment.

Robillard, Bouchard, Fournier, and Renaud (2003) examined the relation between presence and anxiety using a sample that contained both clinically anxious participants ($n = 13$) and non-anxious controls ($n = 13$). The results suggested a strong bivariate relation between self reported presence and anxiety that were provided during exposure to feared virtual environments. However, the study had some methodological limitations. First, presence and anxiety measurements were taken concomitantly during and after the exposure, which may have inflated the strength of the relationship. Second, the study combined the groups of phobics and non-phobics when examining the bivariate relation.

The only study to examine the relation between presence and anxiety in the context of treatment was conducted by Krijn, Emmelkamp, Biemond, et al. (2004) and Krijn, Emmelkamp, Olafsson, et al. (2004). Twenty-four phobic participants undergoing treatment for acrophobia were randomly assigned to either a high ($n = 14$) or low ($n = 10$) presence virtual environment. The high presence environment was created by a computer automated virtual environment (CAVE) which projected the virtual environment on the floor and walls of a compartment. The low presence environment was created by using a head mounted display (HMD), a helmet that contains headphones and screens to present the virtual environment. Four separate environments were used during the course of treatment. Results did not support a bivariate relation between measures of anxiety and presence across any of the sessions in either group. Further, treatment outcomes were comparable for both groups, suggesting presence did not have an effect on treatment outcome. These results provide evidence that there is no relation between presence and anxiety or presence and treatment outcome.

In summary, results from empirical work on the relation between presence and anxiety have been inconclusive. Though a few studies show a positive relation between presence and anxiety (Regenbrecht et al., 1998), these studies have used small, non-clinical samples, and have methodological limitations. The sole study to examine presence in the context of a treatment study using virtual reality reported null findings, but used a small sample as well (Krijn, Emmelkamp, Biemond, et al., 2004; Krijn, Emmelkamp, Olafsson, et al., 2004). Furthermore, virtual reality research in the field of communications has suggested that presence should be examined as a mediator to explain the relation between behavior towards an actual stimulus and behavior towards a virtual stimulus (Lee, 2004). Prior work has focused on the bivariate relationship between presence and in-session anxiety. Given the strong theoretical speculation about the importance of presence in virtual reality exposure and the results from empirical studies, further study of the relations between presence and anxiety in treatment using virtual reality with clinical samples is warranted.

The theoretical assumption regarding the positive impact of presence in the treatment processes has led to the suggestion that presence should be maximized in a treatment setting (Robillard et al., 2003; Wiederhold & Wiederhold, 2005a). However, methods to manipulate presence have been relatively neglected area in the VRE literature. Only one study was found to address this issue, suggesting that augmenting a virtual environment with tactile stimulation was related to an increase in self reported presence (Hoffman, Garcia-Palacios, Carlin, Furness Iii, & Botella-Arbona, 2003). Thus, additional methods to increase a sense of presence during treatment should be explored.

The present study sought to examine the relation of presence, anxiety, and treatment outcome in a treatment outcome study that used a virtual airplane to treat individuals with fear of flying. Based on prior theory (Wiederhold & Wiederhold, 2005a), presence was hypothesized to be positively related to anxiety during exposure to the virtual environment as well as treatment outcome. The relation between presence and in-session anxiety was further explored with the hypothesis that presence mediated relation between phobic anxiety and in-session anxiety. That is, the relation between pre-treatment (phobic) anxiety towards an actual airplane and in-session anxiety when presented with a virtual airplane was hypothesized to be mediated by presence. The final hypothesis of the current study stated that presence was related to the amount of phobic elements in the virtual environment (e.g., a participant that fears take off will feel a greater sense of presence in the virtual plane that includes take off). Phobic elements were defined as the salient aspects of the feared stimulus.

1. Methods

This study examined the data of all participants that were undergoing VRE as part of a randomized clinical trial comparing virtual reality exposure therapy and in vivo exposure therapy to a wait list control for the treatment of fear of flying. The current study utilized data from all individuals who were treated with virtual reality exposure therapy (see Rothbaum, Hodges, & Smith, 1999, for details).

1.1. Participants

Participants were 36 individuals who met DSM-IV (APA, 1995) criteria for one of the following anxiety disorders: specific phobia, situational type (85%, $n = 31$); or panic disorder with agoraphobia (15%, $n = 5$) with flying as the predominantly feared stimulus. Participants were recruited through a newspaper advertisement. The majority of the sample received a single diagnosis (61%, $n = 22$). Diagnoses were made during a pre-treatment assessment. All diagnoses were made using the Standard Diagnostic Interview for the DSM-IV (SCID: First, Gibbon, Spitzer, & Williams, 2002) conducted by a licensed psychologist. A second licensed psychologist rated both diagnostic interviews and the two raters demonstrated excellent interrater reliability with a kappa coefficient of 0.94. Participants self identified as primarily Caucasian (85%), female (85%), and married (63%) with a mean age of 39. The majority of the sample was well educated (16.2 mean years of education) and of high social economic status with the majority of the sample having an annual income greater than \$50,000 (83%).

1.2. Measures

1.2.1. Fear of Flying Inventory (FFI: Scott, 1987)—The FFI is a 33-item measure assessing fear of flying intensity. Fear of flying is rated on a nine-point scale ranging from 0 (not at all) to 8 (very severely disturbing). The current Cronbach's alpha was $\alpha = 0.95$.

1.2.2. Questionnaire on Attitudes Toward Flying (QAF: Howard, Murphy, & Clarke, 1983)—The QAF was used to assess the number of phobic elements included in the virtual airplane for each participant. The QAF provides a list of 36 items that assesses fear towards specific aspects of flying on an 11-point (0–10) scale. Twenty of the items referred to aspects of flying that were included in the virtual airplane. The number of items that were rated 8 or greater, indicating extreme fear, was tallied for each participant. This provides a measure of the amount of phobic elements that were included in the virtual environment for each participant.

1.2.3. Presence Questionnaire (P-BF: Witmer & Singer, 1998)—The original Presence Questionnaire was modified for the original treatment outcome study to include only those items that were applicable to virtual reality exposure therapy. The original measure consisted of 32 items across 6 subscales: involvement/control, naturalness, auditory stimulation, haptic response, resolution, and interface quality. Based upon feedback provided by clients who were undergoing VRE for fear of flying, but not part of the current study, two licensed psychologists reviewed the measure and removed items that were agreed to be unrelated to VRE. These items loaded on the subscales of haptic response (e.g., how well could you move or manipulate objects in the virtual environment?), resolution quality (e.g., how well could you closely examine objects?), and interface quality (e.g. how much did the control devices interfere with the performance of assigned tasks or with other activities?). The remaining items were those with the highest factor loadings based on the prior factor analysis (Witmer & Singer, 1998) and primarily assessed involvement (11 items), naturalness of the environment (2 items), and auditory cues (2 items). Responses were measured on a 7-point (1–7) scale. The current Cronbach's alpha was $\alpha = 0.86$.

1.2.4. Subjective Unit of Discomfort Scale (SUDs: Wolpe, 1973)—The SUDs rating scale is a face valid self report measurement of anxiety on a 0–100-point scale. Scores of 0 represent no fear and 100 represents the most fear the individual has ever felt in their life. For this study, the highest SUDs rating for the first exposure therapy session was used.

1.3. Procedure

Participants completed eight individual sessions of treatment across 6 weeks according to a treatment manual (Rothbaum et al., 1999). The first four sessions of treatment consisted of anxiety management and skills training, including breathing relaxation and cognitive restructuring. Exposure to the virtual environment occurred during the final four sessions which took place twice a week in the therapist's office. During exposure, the individual was exposed to a virtual plane that was displayed through a head mounted display (HMD). Exposure sessions were conducted according to an individualized fear hierarchy and included many aspects of flying including sitting on the virtual plane with the engines off; sitting on the plane with the engines on; taxiing on the runway; take off; a smooth flight; landing; and a turbulent flight. All of these conditions were controlled by the therapist using the computer that was connected to the HMD. During the session, the therapist remained in contact with the client through a microphone that broadcast to the headphones of the HMD. SUDs ratings were taken in 5 min intervals throughout the therapy session. The therapist encouraged sustained attention to the virtual environment and moved appropriately through a fear hierarchy to allow clients to habituate.

2. Results

Descriptive statistics for all variables are presented in Table 1. Scores for the FFI and Presence Questionnaire indicate the mean item response, such that the possible range of scores on the FFI was 0–8 and on the Presence Questionnaire was 1–7. Each variable was assessed for outliers, which were defined as scores 1.5 times greater or less than the interquartile range (Tabachnick & Fidell, 2001). One outlier was identified and removed from the analyses reducing the sample size to 35. This participant denied experiencing anxiety during VRE and reported a SUDs rating of 0. All of the analyses were repeated using only the participants who were diagnosed with specific phobia ($n = 30$) to assess a possible confounding effect of using a sample with heterogeneous diagnoses. Results were consistent with those of the larger sample ($n = 35$) and so the findings of the larger sample were reported.

The relation between presence, as assessed by the Presence Questionnaire, and in-session anxiety, as assessed by SUDs ratings, was measured using a univariate regression. Scores on the Presence Questionnaire accounted for a significant amount of variance in SUDs ratings, $F(1, 33) = 10.37, p < 0.01, R^2 = 0.24$. This supported a linear relation between presence and in-session anxiety such that higher presence was related to greater in-session anxiety, $b = 9.3, S.E. = 2.88, p < 0.01$.

The relation between presence and in-session anxiety was further examined by assessing whether or not presence mediated the relation between pre-treatment anxiety and in-session anxiety. The mediation was examined using three separate regressions according to the guidelines of Baron and Kenny (1986; Table 2). The first regression established a significant relation between the independent variable, pre-treatment FFI scores, and the mediating variable, Presence Questionnaire scores, $F(1, 33) = 4.30, p < 0.05, R^2 = 0.12$. The second regression, established a significant relation between the independent variable, pre-treatment FFI scores, and the dependent variable, SUDs ratings, $F(1, 33) = 4.50, p < 0.05, R^2 = 0.12$. In the third regression, SUDs ratings were regressed on the Presence Questionnaire scores and pre-treatment FFI scores. Presence Questionnaire scores and pre-treatment FFI scores accounted for a significant amount of variance in SUDs ratings, $F(1, 32) = 6.89, p < 0.01, R^2 = 0.16$. The relation between pre-treatment FFI scores and SUDs ratings were no longer significant when Presence Questionnaire scores were included in the regression model, $b = 2.97, S.E. = 2.33, p = 0.21$. The indirect effect of pre-treatment FFI scores on SUDs ratings via Presence Questionnaire scores ($\beta = 0.14$) explained approximately 41% of the total effect between pre-treatment FFI scores on SUDs ratings ($\beta = 0.35$). These findings suggested that presence had a moderate mediation effect on the relation between pre-treatment anxiety and in-session anxiety.

The relation between presence and the amount of phobic elements included in the virtual environment was assessed with a bivariate correlation. Presence Questionnaire scores were significantly positively correlated to the amount of phobic elements, $r = 0.47, p < 0.01, R^2 = 0.22$. This indicates changes in presence were related to the amount of phobic elements in the virtual environment.

Finally, a hierarchical regression was used to determine if presence was related to treatment outcome (Table 3). After controlling for pre-FFI scores, Presence Questionnaire scores were not significantly related to post-FFI scores, $F(1, 32) = 0.01, p = 0.94, R_{\text{change}}^2 = .00$. This suggested that presence was not related to treatment outcome.

3. Discussion

The current study sought to add to prior work on presence by investigating the relation between presence and the following variables: in-session anxiety, the number of phobic elements included in the virtual environment, and treatment outcome. One important finding from the current study is the positive relation between self reported presence and in-session anxiety. The majority of prior literature on this topic has been theoretical (Wiederhold & Wiederhold, 2000), and the two studies that empirically examined the relation with a clinical sample had contradictory findings (Krijn, Emmelkamp, Biemond, et al., 2004; Krijn, Emmelkamp, Olafsson, et al., 2004; Robillard et al., 2003). In a sample of acrophobics, Krijn, Emmelkamp, Biemond, et al. (2004) and Krijn, Emmelkamp, Olafsson, et al. (2004) did not find a relation between presence and anxiety using two different types of virtual reality technology, an HMD ($n = 10$) and a computer automatic virtual environment (CAVE; $n = 14$), a format of virtual reality that is hypothesized to elicit a greater sense of presence. However, the null findings may be attributed to a lack of power to detect differences between the groups. In a sample of individuals with specific phobia, Robillard et al. (2003)

found a linear relation between presence and anxiety. However, presence and anxiety were measured by one item self report ratings that were taken concomitantly, which may have inflated the relation. The findings of the current study corroborated those of Robillard et al. and improved upon its methodology by measuring presence and anxiety separately and assessing presence with a questionnaire with good psychometric properties. Thus, results from the current study add to the small literature supporting the hypothesis that an increased amount of presence is related to an increased amount of anxiety in individuals with a specific phobia.

Another important finding was that presence served as a mediator of the relation between pre-treatment anxiety and in-session anxiety. This finding suggested that presence functions as the conduit that enabled phobic anxiety to be felt during exposure, and implied that a sense of presence may have been necessary to experience anxiety during exposure to a virtual environment. Results also suggested that those with greater phobic anxiety may experience more presence, which will lead to a greater amount of anxiety during exposure. Thus, VRE may be most effective for those that are highly phobic. The relation between presence and anxiety may be stronger for highly phobic individuals as research suggests they show an anxious response when presented with only a vague representation of their feared stimuli such as a picture or shadow (Levin, Cook, & Lang, 1982). This interpretation is consistent with the only other study that has investigated presence and VRE with a clinical sample (Krijn, Emmelkamp, Biemond, et al., 2004; Krijn, Emmelkamp, Olafsson, et al., 2004). This study found that acrophobics who had lower fear prior to beginning treatment felt less present and anxious during exposure and ultimately dropped out of the study.

Conceptualizing presence as the conduit that enables anxiety to be felt during exposure illuminated the null findings from prior studies that failed to support a relation between presence and anxiety in a non-clinical sample (Regenbrecht et al., 1998). These participants may have experienced relatively low levels of anxiety prior to engaging in the virtual environment, which may have prevented the non-clinical participants from experiencing sufficient presence to become anxious during exposure. A careful review of the descriptive statistics suggested that this may have occurred as participants did not endorse high levels of anxiety prior to exposure ($M = 1.05$, $S.D. = 0.58$, range = 0–6). Additionally, Robillard et al. (2003) found that phobic individuals reported higher presence scores than non-phobics. The significant difference between the phobic and non-phobic groups in the Robillard et al. study, the contrast between Regenbrecht et al.'s null results, and the significant findings of the current study suggest future research on presence and anxiety should be conducted with clinical samples.

Finally, the findings suggest that presence was not directly related to treatment outcome. The emotion processing theory provides a theoretical framework to consider this null finding (Foa & Kozak, 1986). The theory suggests that a phobic fear structure must be activated in order to obtain treatment outcome. Once activated, therapeutic outcome occurs through prolonged, repeated, and controlled exposure to the feared stimulus, which leads to habituation and the extinction of fear. Exposure to the feared stimulus alone will not result in successful treatment outcome. Thus, presence may be necessary to elicit anxiety during exposure so that habituation can occur, but is insufficient by itself to obtain positive treatment change. The lack of support for the relation between presence and treatment outcome indicates that simply placing oneself in the virtual environment alone is unlikely to cause a reduction in anxiety.

The study had several limitations of note, the most prominent of which was the use of a small sample ($n = 35$). The results should be interpreted with caution until they are replicated. The mixed findings of prior work, all of which used smaller samples, further

emphasizes the need for replication. Second, all of the measures used in the current study were self report, which makes it difficult to disentangle the measurements of in-session anxiety and presence. Self report measures are prone to bias and so the measurement of presence may have been influenced by the anxiety felt during exposure. Third, the presence measure used in the current study was modified to be relevant for virtual reality exposure. This may have reduced the validity of the presence construct in the current study. A measure of presence as it pertains to VRE should be developed. Fourth, the results suggested that presence moderately mediated the relation between pre-treatment anxiety and in-session anxiety; thus, it is possible that there are other mediators of this relation. Again, future studies with larger samples are needed in order to examine other potential mediating variables. Finally, the current study combined individuals with panic disorder with and without agoraphobia with those who had specific phobia. In the larger treatment study, there were no differences in treatment outcome or presence amongst these groups. However, the impact of presence may vary as a function of the anxiety disorder. Future work with larger, homogenous samples should be conducted to examine the role of presence for individuals with different anxiety disorders.

Future work on presence in VRE should further examine the impact of phobic elements. The current study provides strong preliminary results that increased presence is associated with the inclusion of more phobic elements in the virtual environment. In the current study, mean amount of self reported phobic elements ($M = 10.26$) was approximately a third of the potential phobic elements as assessed by the QAF ($N = 36$). Although some of these elements may not be feasible to recreate, such as gravitational pull during take off, the influence of including a greater number of phobic elements on presence and the treatment process should be investigated. Thus, virtual environment developers should work with scholars of anxiety to identify the most likely phobic elements and include as many as possible in the virtual environment. For example, a chair with a large subwoofer was used in the current study to simulate the tactile sensations of take off and landing, two of the highest endorsed feared aspects of flying. Although not directly tested in this study, it also seems reasonable that during exposure, the therapist should attempt to recreate the phobic elements to supplement the visual and auditory cues of the HMD. Recreating phobic elements requires the therapist to know the idiosyncratic phobic elements for each client and be creative in incorporating them into the exposure, especially if the important phobic elements are not represented in the virtual environment.

Additional studies should determine the extent that other sensory modalities can improve an experience of presence. Hoffman et al. (2003) supported a relation between increased presence and the inclusion of tactile stimulation in VRE with spider phobics. A recent discussion of VR has suggested that presence may also be influenced by olfactory sensations (Fabrizio, Holmberg, & Lundstrom, 2001).

Finally, the current study focused on presence at the first session of VRE. As habituation towards the feared stimulus is presumed to occur over the course of treatment, the relation between presence and anxiety may change. It may be the case that at mid-treatment, presence no longer mediates the relation between pre-treatment (phobic) anxiety and in-session anxiety because of a decrease in phobic anxiety. Alternatively, the relation between anxiety and presence may remain stable over treatment because of the use of fear hierarchies. As a client habituates to the less feared items on the hierarchy, the client confronts more highly feared aspects. As a result, the relation between presence and anxiety may remain stable over the course of treatment. Future studies should determine if the relation between presence and anxiety fluctuates over the course of treatment.

In summary, the current study explored the function of presence in VRE. The results support presence as a conduit that enabled phobic anxiety to be expressed during exposure to a virtual environment. However, presence was not supported as contributing to treatment outcome. This suggests feeling present during exposure may be necessary but not sufficient to achieve benefit from VRE.

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Table 1

Correlation and descriptive statistics of variables

	Pre-FFI	Post-FFI	Presence	In-session anxiety	Phobic elements
Pre-FFI	1.00				
Post-FFI	0.49**	1.00			
Presence	0.34*	0.18	1.00		
SUDs ratings	0.35*	0.37*	0.49**	1.00	
Phobic elements	0.73**	0.42**	0.47**	0.31	1.00
Mean	3.55	2.89	4.65	63.00	10.26
S.D.	1.20	1.34	0.72	17.54	5.63

Note: $n = 35$. FFI: Fear of Flying Inventory. Presence: Presence Questionnaire. SUDs Ratings: Subjective Unit of Discomfort Rating.

* Significant at $p < 0.05$.

** Significant at $p < 0.01$.

Table 2
Regressions assessing presence as a mediator of the relation between pre treatment anxiety and in-session anxiety

Dependent variable	Step	Variables	b	S.E.	β	t	R ²	F
Presence	1	Pre-FFI	0.26	0.13	0.34	2.07 [*]	0.12	4.30 [*]
SUDs ratings	2	Pre-FFI	5.05	2.38	0.35	2.12 [*]	0.12	4.50 [*]
SUDs ratings	3	Pre-FFI Presence	2.97 7.96	2.33 3.03	0.20 0.42	1.27 2.63 ^{**}	0.16	6.89 ^{**}

Note: FFI = Fear of Flying Inventory. Presence: Presence Questionnaire, SUDs Ratings: Subjective Unit of Discomfort Rating.

^{*} Significant at $p < 0.05$.

^{**} Significant at $p < 0.01$.

Table 3
Multiple regression assessing the relation between presence and treatment outcome

Dependent variable	Step	Variables	b	S.E.	β	t	R ² change	F change
Post-FFI	1	Pre-FFI	0.54	0.17	0.49	3.23**	0.24	10.40**
	2	Pre-FFI Presence	0.54 0.02	0.18 0.24	0.49 0.01	3.23** 0.07	0.00	0.01

Note: FFI: Fear of Flying Inventory. Presence: Presence Questionnaire.

* Significant at $p < 0.05$.

** Significant at $p < 0.01$.