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Measuring the Sense of Presence and its Relations to Fear of Heights in Virtual Environments

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This article describes a study in which a genuine effect of presence—the development of fear of virtual stimuli—was provoked. Using a self-report questionnaire, the sense of presence within this situation was measured. It was shown that fear increased with higher presence. The method, which involved 37 test participants, was tested and validated with user tests at the Bauhaus University. A growing body of research in human–computer interface design for virtual environments (VE) concentrates on the problem of how to involve the user in the VE. This effect, usually called immersion or the sense of presence, has been the subject of much research activity. This research focuses on the influence of technical and technological parameters on the sense of presence. However, little work has been done on the effects of experienced sense of presence. One field in which a sense of presence is necessary for the successful application of VEs is the treatment of acrophobic patients. Our goals are to (a) create a theory-based self-report measurement for presence and (b) measure presence independently from specific effects to validate the measurement. The anxiety resulting from the confrontation with a virtual cliff is used to validate the measurement of presence.

1. INTRODUCTION

The sense of presence in virtual environments (VEs) is widely acknowledged as a defining and central element of the experience called virtual reality (VR; Steuer,

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1992). It is probably the most natural and at the same time the most surprising observation we can make about VR: the most natural during the experience, in which feeling present seems unquestionable, and the most surprising during the observation of somebody else immersed in a VE. The presence reached in a VE seems to determine the usefulness of many of the serious applications of VEs, such as air traffic control, battlefield simulations, and telepresence surgery. In general, all applications that involve a knowledge transfer between the experiences in virtual and real environments seem to need a high degree of presence (e.g., training environments in which a skill transfer from training in a VE to the real world is desired or the use of interface metaphors that build on the transfer of expectations from the real world). Furthermore, VR applications are now built specifically for the purpose of creating experiences with a high sense of presence (Davies, 1995). In all of these instances, a better understanding of presence, its prerequisites, and its impacts is necessary.

VR means that the user experiences a mediated environment as if it were real, but the term *real* by no means refers to a state in which the user is unable to distinguish between reality and VR. Rather, in most cases, the user acknowledges that the experience is a result of mediated stimuli. To conceptualize this seemingly paradox experience, the terms *presence* and *immersion* are used.

Unfortunately, they are often used synonymously. To lay the ground for the following argumentation, we want to distinguish between these two terms (Bente & Otto, 1996; Slater & Usoh, 1993a, 1993b; Steuer, 1992). The term *immersion* is reserved to describe all hardware and software elements that are needed to present stimuli to the user's senses. These mediated stimuli are perceived by the user and thus are describable objectively. Properties of the visual stimuli found to be important are the fidelity of resolution; extractability of cues for three dimensionality; the field of view (Hendrix, 1994); or symbolic, geometric, and dynamic information (Ellis, 1995). Properties of the hardware, such as the weight of head- or body-mounted gear, distracting cables, and so on, also have to be regarded as important (Barfield, Hendrix, Bjorneseth, Kacmarek, & Loutens, 1995; Barfield & Weghorst, 1993). The question arises, however, for what exactly these properties are important. We assume that the hardware elements influence how the user experiences the VE. However, hardware elements are not the only factor; they interact with personal and situational variables. In our regard, the central element of the user's experience is the feeling of presence. We want to conceptualize immersion as distinct from the subjective experience of presence (cf. Sheridan, 1992; Slater & Usoh, 1993a).

A variety of definitions has been proposed for the concept of presence. Lombard and Ditton (1997), who stated that presence can be defined as the perceptual illusion of nonmediation, provided this definition: "The illusion of nonmediation can occur in two distinct ways: (a) The medium can appear to be invisible or transparent … and (b) the medium can appear to be transformed into something other than a medium, a social entity" (p. 34). Although we agree with this observation, we think that those definitions are not precise enough when we want to use them for research or design decisions. It seems to be necessary to go a step further and describe the state of presence in terms of the individual's cognition.

Attempts in this direction have been made by a variety of definitions describing presence as a distinct feature of the user's spatial cognition. Steuer (1992) stated: "Presence is defined as the sense of being in an environment" (p. 75). Sheridan (1992) described presence as "a sense of being physically present with virtual object(s)" (p. 120). Welch (1996) noted that "presence is essentially the same as 'telepresence,' the experience reported by teleoperator users of being in the same distant physical location as the devices they are controlling" (p. 263). All of these definitions have in common an emphasis on the perception of a three-dimensional space of which the user feels a part. These concepts are mainly built on the work of Gibson (1979). Recent empirical research programs of, for instance, Slater and Usoh (1993a, 1993b) or Prothero, Parker, Furness, and Wells (1995) show that this approach is useful for our understanding of the perception of VR.

Lombard and Ditton (1997) called this idea the metaphor of presence as transportation. They described three types of this metaphor: First, there is the concept of "you are there," in which the user experiences a transportation to another place. Second, some technologies provide an "it is here" concept in which mediated objects are experienced as sharing the real room with the user. Finally, a "we are together" concept refers to the fact that two or more users experience a space as shared, which can happen in real or virtual spaces. We think that formulating these observations in cognitive terms provides a better understanding of the involved processes (cf. Sheridan, 1992).

Building on these ideas, we want to present a model of presence. This conceptualization starts with the following assumption: A mental model of the surrounding environment is formed on the basis of sensory experiences and memory. This model is egocentric: The body is the central point and fundamental basis. Virtual stimuli can be regarded as relevant to the model construction and can be then included in the model. Thus, they become part of the same space that the body inhabits: A shared space is constructed. Whether the basis of the space emerges from virtual or real stimuli decides which transportation metaphor is applicable: Users of a fully immersive head-mounted display are likely to construct the basis out of the stimuli provided by the VE and thus become transported "there." Users experiencing a three-dimensional object on a screen using shutter glasses experience a virtual object placed in the real room between their eyes and the screen surface: The virtual object is "here." Finally, in a conferencing system that provides visual information of a distant room, a shared space can be constructed out of the real room and the mediated one. However, virtual objects are not always included in the user's environmental space. When we see a photo, we construct a three-dimensional model of the space visible in the photo (if there is one), but we keep this space distinct from the conception of our own environment. The combination of these two rooms is the point where presence starts to happen.

Now a further point can be made by referring to the paradox of experiencing virtual stimuli as real. By acknowledging the virtual objects as sharing the environmental space with him or her, the user projects the perceived (felt) reality of his or her own body onto the virtual objects. The virtual objects are experienced as real even if any sense of photorealism is absent. This projection results from the interaction between the user's body and the virtual objects. Three examples should illustrate this idea:

- A common feature of immersive VEs is that turning and moving the head is tracked and has an immediate effect on the presented view. Technically speaking, the head movement is translated into the movement of a camera in the virtual space. But we perceive this as natural, not as directing a camera with our head. The mediating metaphor disappears, and an integrative mental model is built. In fact, the body is already acting as if it were inside the environment. When the perceptions fit into our model of the environment, body and virtual objects seem to share the same world.
- A second example is provided by Hoffman's experiments with tactile augmentation, in which physical objects that correspond to virtual objects are used to give tactile feedback. In this case, actions result in fitting perceptions in the visual and the tactile field. Fitting tactile perceptions increases the sense of reality, which is projected from the body onto touched objects and then onto other objects as well (Carlin, Hoffman, & Weghorst, 1997; Hoffman et al., 1996).
- A third example is given by Foerster (1992) in experiments with three-dimensional representations of four-dimensional objects. Only those participants who were allowed to interact (move and rotate) with the objects mastered the experimental tasks and "realized" the fourth dimension. Passive observers only achieved an intellectual understanding of the objects. Additionally, Foerster noted that the resistance of the joysticks that were used to rotate the four-dimensional object was translated into a notion of weight felt by the participants. Again, interaction with objects produces a model of the environment in which body and virtual objects are brought together and inferences about reality are drawn from this model.

2. MEASURES OF PRESENCE

A variety of measures of presence have been proposed. First, a distinction can be made between objective and subjective measures (Jex, 1988; Sheridan, 1992). A well-known example for objective methods is the use of conditioned or unconditioned reflexes, for example, reflex movements as reactions to unexpected fast-moving objects (Held & Durlach, 1991) or socially conditioned responses (Sheridan, 1992). Further methods for extensive data collection in related fields have been proposed but remain theoretically isolated from sense of presence (e.g., Altorfer, Jossen, & Würmle, 1997; Strickland & Chartier, 1997). Other objective measures in VE involving tasks may be task demands, task results, and correlated measures (Jex, 1988) as well as training efficiency (Sheridan, 1992). Objective measurement based on participant's room perception has been proposed by Prothero et al. (1995). Barfield and Weghorst (1993) introduced the measurement of disorientation and physiological responses. They remarked that "just as humans experience changes in physiological parameters in response to novel or unusual stimuli as the sense of presence increases within a VE, the participant should experience similar physiological changes" (p. 702).

One problem with these types of measures is their specificity. In most cases, they need an extra setup in the VE, or they are applicable in only certain types of situations (such as the task measurements). Additionally, the results may interact with other features of the VE so that comparison between different VEs becomes difficult or even impossible. However, the observation that presence can have measurable impacts in certain situations may prove useful for the validation of other, more general measures.

The most frequently used type of subjective measure is the questionnaire (Sheridan, 1992). Various scales have been developed and used in the last years. Questionnaires with some questions related to presence come from Slater, Usoh, and Steed (1994; adapted by Carlin et al., 1997) and Hendrix (1994). A recent one-item measure was used by Towell and Towell (1997) to measure social presence in text-based VEs. This item also refers to the notion of a shared space, as described earlier here. Sometimes, the theoretical basis for the questions remains unclear. Some questions do not fit into the theoretical model presented here; for example, the question "How realistic did the virtual world appear to you?" by Hendrix can be understood as referring to some kind of photorealism. Following our model, however, even a totally abstract VE can generate a high degree of presence. Nevertheless, these approaches have shown that the use of questionnaires can be useful to measure presence. In general, questionnaires are relatively parsimonious and can be applied regardless of the VE in use.

Witmer and Singer developed the most comprehensive questionnaire (Singer & Witmer, 1997; Witmer & Singer, 1994). They designed two scales: the Immersive Tendencies Questionnaire and a Presence Questionnaire, both with 32 questions. Data collected with the Presence Questionnaire showed an inverse relation between presence and simulator sickness and a positive (but sometimes absent) relation between presence and task performance. Additionally, they searched for item clusters and found five subscales. From these clusters, it is clear that a great amount of questions address the subjective evaluation of what we call immersion. Only the involvement cluster asks for subjective states and feelings, thus capturing presence. Nevertheless, this questionnaire, especially this subscale, seems to be a very promising attempt to create a subjective measurement.

3. IMPACTS OF PRESENCE

Although subjective measures may be the method of choice in most situations, objective measures may still be of interest for validation purposes. This poses the question of which impacts of presence have been reported so far.

During the past years, some links between a person's sense of presence and task performance, spatial awareness, memory, and enjoyment have been found (Heeter, 1995; Sheridan, 1992; Taylor, 1997; Witmer & Singer, 1994). In addition, Witmer and Singer (1994) explored a negative correlation to simulator sickness, which is a very serious problem in bringing VR to real usage. The investigations mentioned here have shown that presence could be a necessary feature for VEs. Only Ellis (1996) emphasized a possible disturbing influence of the sense of presence on task performance in complex virtual information environments.

We now want to turn to a fascinating example for Barfield and Weghorst's (1993) observation cited earlier that VEs may elicit the same physiological (and, in this case, psychological) effects as the corresponding real situations. This is one of the most promising applications of VEs: the treatment of mental disorders (North, North, & Coble, 1996) such as phobias. The whole idea of phobia treatment in VEs is based on this effect, because for a successful acrophobia treatment, it is important to provoke the same physiological reactions as those that occur in situations in which real heights are encountered. Thus, because of the high practical relevance of this topic, we now want to focus on this effect.

Since the first proposal of VR treatment of mental disorders (North et al., 1996), a number of studies have investigated this field. Rothbaum et al. (1995a, 1995b) undertook the first empirical studies with participants suffering from fear of height (acrophobia). Recently, further experiments have investigated fear of spiders (Carlin et al., 1997) and fear of flying (Hodges, Rothbaum, Watson, Kessler, & Opdyke, 1996). Some proposals were also made to treat test anxiety with VR techniques (Knox, Schacht, & Turner, 1993).

Rothbaum et al. (1995a, 1995b) developed a VR system to treat patients suffering from acrophobia. In these experiments, phobic patients were confronted in VR with anxiety-producing situations, such as riding an elevator, standing on a bridge, and so forth. They had to cope with these situations until their fear decreased and then proceed to the next level. This technique, called *systematic desensitization*, is a common and successful psychological treatment method traditionally used with imagined or real-world fear-producing situations. The published reports allow the conclusion that there is serious potential for the use of VEs in therapeutic interventions such as desensitization, at least in combination with common methods. These reports repeatedly point out that the participants develop physiological and psychological effects equivalent to the feared real-world situation. Thus, the use of this procedure for investigating presence effects seems both useful for the phobia treatment research and promising for assessing data concerning validity and usefulness of presence measures.

4. THE STUDY

4.1. Paradigm

Incorporating the experiences from the previous sections, we devised the following design for our study. The goals of the study were to (a) provide and investigate a situation in which a genuine effect of presence could be observed. In this situation, we wanted to (b) study how differential effects of interacting with the virtual world could be predicted by measuring presence.

For the purpose of the first goal, we aimed at provoking physiological and psychological reactions by presenting virtual stimuli resembling real emotion-producing stimuli. In terms of our model, we assumed that these participants could build a mental model of the space that included both themselves and the virtual stimuli. The situation constructed in this mental model provoked the emotion. The stimuli had to be chosen in a way such that they elicited measurable effects only if the participants felt themselves present in the VE.

Building on the work done by Rothbaum et al. (1995a, 1995b) at Georgia Tech, we chose fear of height as the topic of our experiment. The relation between fear (or anxiety) and presence has already been acknowledged by the Georgia Tech group. Kooper (1994), for instance, wrote that "the SUD [subjective units of discomfort; a technique for measuring anxiety] were used by us to get an idea of presence" (p. 49). We think that the perception of a virtual cliff should only result in anxiety and fear if the person actually perceives himself or herself confronted with the height. Just looking at a picture (not experiencing presence) should not create fear. It is interesting to note that we do not assume that perceiving the VE as "real" with all of its connotations is necessary for anxiety to develop. Instead, the construction of a VE enveloping the real self should suffice.

To pursue the second goal, we aimed at measuring presence and trying to predict the effects observed in the first goal. Thus, we developed a questionnaire for the sense of presence on the basis of the theoretical model and previously published scales. We hypothesized a positive relation between the presence measure and the effect measure of anxiety in the virtual world.

As mentioned earlier, we took the inspiration for our study from the work done by Rothbaum et al. (1995a, 1995b) on the treatment of acrophobia in VEs. However, in contrast to the Georgia Tech experiments, we did not want to work with phobic patients for two reasons. First, because we focused our work on presence instead of on phobia treatment, confronting phobic patients seemed unwarranted because we were not able to provide the context of an extended therapeutic procedure. Second, the research method should be applicable to nonphobic participants in the future. Thus, we planned the experiment with nonphobic participants. This made it necessary to expand the design of our experiment. First, we had to distinguish between two different forms of fear: (a) fear as a personality trait, a stable attribute constant across situations; and (b) state fear, the actually experienced anxiety in the confrontation situation. It is implausible to assume that participants low in trait acrophobia would show high state anxiety when confronted with a virtual height even when highly present in the VE. Second, we assumed that because our participants did not have the goal of conquering a phobia, they would probably adjust their behavior during the confrontation to diminish anxiety. Thus, we took into account the general avoidance behavior shown by the participants in situations involving height.

We hypothesized that trait fear increases and the avoidance decreases the actual state anxiety in the confrontation situation. Additionally, following our model, presence should contribute to these influences and have a positive effect on state anxiety.

Thus, our design incorporated three factors: trait acrophobia, avoidance behavior as a trait, and presence. We decided not to manipulate presence experimentally but to measure it. This was done to test and validate the measurement method and to provide a paradigm that can be useful in evaluation studies in general. The planned analysis was to regress the measured state anxiety on the three predictor variables.

4.2. Participants

Participants in this study were 37 students and employees of the Universities of Weimar and Jena in Germany. Twenty three were men and 14 were women; the mean age was 27, ranging from 20 to 46. The experiment was advertised as part of a usability study of VEs. No mention of acrophobia or heights was made in the advertising. The experiment was accompanied by a second study that took place following the one presented here, having no relation to acrophobia. The participants were not paid for their participation. To thank them, they were given photos of their own exploration of the VE. However, they were not aware of being photographed during the experiment. The participants had no or very little prior experience with VEs.

4.3. Apparatus

The VE presented to the participants included a virtual cliff approximately 8 m high. We assumed that height was one of the most suitable stimuli for our purpose because fear should be developed only if the participant places himself or herself mentally in front of the cliff. (Thus, the difference between participants experiencing presence and participants not experiencing presence should be maximized.) A cliff 8 m deep should be sufficient for nonclinical participants. The depth was chosen after preliminary considerations about our own feelings in this situation.

Unlike Rothbaum et al. (1995a, 1995b) at Georgia Tech, we did not use elevators because of possible inconsistencies related to speed and velocity between the real and virtual world experience. Rather, we lowered the ground. Sufficient visual depth cues were provided using linear perspective enhancing lines at edges, special face coloring, and some architectural elements as a reference frame that appeared at the beginning of the session. Although the equipment available at the laboratory of the Bauhaus University was relatively simple (no advanced lighting techniques, no texturing, simple scene setup), the VE did nevertheless look realistic. Industrial designers and architects supported this effort.

Building on the literature on presence questionnaires discussed earlier, we developed a German questionnaire specifically designed to measure the sense of presence. The questions were taken from interviews with long-term users of VR applications. They assessed feelings of involvement and of presence-related spatial mental model construction. Furthermore, modified translations of items from Slater et al. (1994) and Hendrix (1994) were included. The final questionnaire consisted of 14 items to be answered on 5-point Likert-type scales ranging from −2 (*fully disagree*) to 2 (*fully agree*). The questionnaire is available from the first author on request.

For measuring the state anxiety, we chose the state scale of the State–Trait Anxiety Index by Laux, Glanzman, Schaffner, and Spielberger (1981). This questionnaire consisted of 20 items and assessed the experienced physiological symptoms of arousal and the anxiety felt by the participant and was scaled as a 4-point Likert-type scale. Thus, it measures both the physiological and psychological effects of encountering a dangerous situation.

Furthermore, with 20 additional items, the traits acrophobia (7-point Likert-type) and avoidance behavior (3-point Likert-type) concerning heights were measured. For this purpose, the scales from Cohen (1977) were applied that were used by Rothbaum et al. (1995a, 1995b).

4.4. System

The hardware of the atelier, virtual, where the experiment took place, consisted of a Silicon Graphics Workstation, a monoscopic color head-mounted display (VR4) with Polhemus tracking devices, and the platform (a furniture construction that provides the user with an almost unrestricted interaction space of about 4 m in diameter; Figure 1).

This equipment was used in the past to teach students in VR and to undertake some other experiments on human–computer interfaces (Regenbrecht & Donath, 1997). The software (the virtual world) was designed especially for the tests. Figure 2 shows a view of the environment from inside. The whole environment was tested before the actual test series with approximately two dozen participants to get reasonable reliability.

4.5. Procedure

Before the tests, the participants filled out the questionnaires about their fear of heights as a trait and their avoidance behavior. Thus, before the actual immersion in the VE, they were made aware of the fact that the experiment involved virtual heights. They were informed that the experimenters would not talk to them during the experiment and that they had to fulfill a task. However, they were told that they

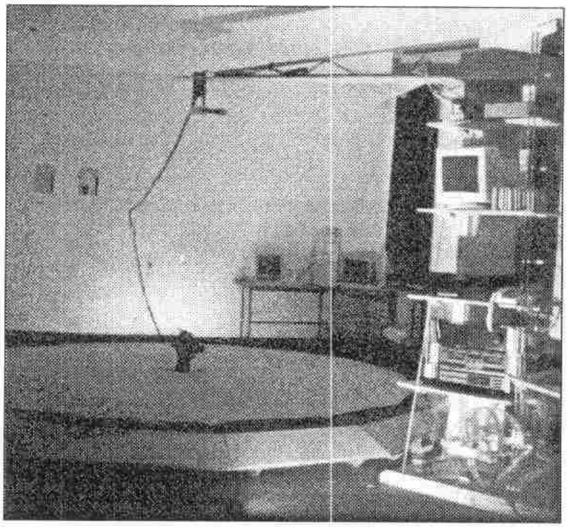

FIGURE 1 The real environment used for the experiment.

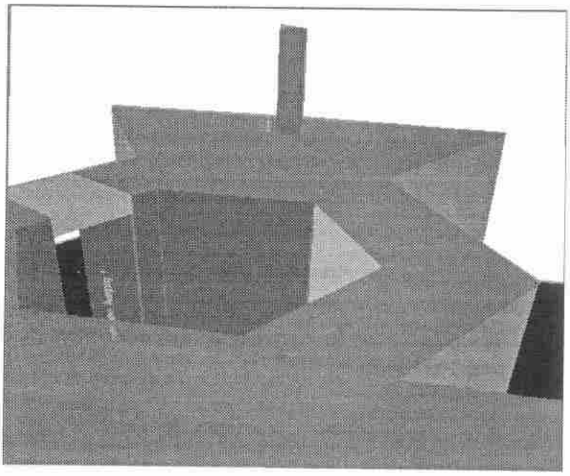

FIGURE 2 An inside view of the virtual environment.

could cancel the experiment at any time. Following these instructions, they were made familiar with the head-mounted display and entered the virtual world.

The task for the participants was simply to search for some texts that appeared in the virtual world and to obey the instructions stated by these texts. At the beginning, the participants were given time to adjust themselves to the VE by just walking around without any particular task. During this time only, the initial state of the system was presented: a floor without any holes or cliffs. After approximately 2 min, some parts of the VE were lowered continuously to a level of about 8 m below ground level. By showing the first text, it was made sure that the participants were aware of the lowering ground. The instructions were formulated and placed in such a way that they forced the participants to move around in the virtual space. The texts were placed close to the zero level so that each participant would notice the virtual depth. The participants had to choose one of three different paths to fulfill the first tasks: either one of two different small bridges or simply straight across the virtual depth (Figure 2). All tasks were completed if they found an exit symbol. Typically, the participants stayed for 20 min in the VE. If they did not complete all tasks after 20 min, they were interrupted by the experimenters and the experiment was terminated.

Immediately following their stay in the VE, the participants were asked to fill out the questionnaires about their anxiety during the confrontation and the experienced presence. The participants were undisturbed throughout the entire test. The participants' reactions to the height (depth) were observed and recorded on tape.

5. RESULTS

Thirty-seven participants took part in the experiment. One participant was not included in the analysis because of irregular conditions in his case. From a second participant, state anxiety values are not available because of database faults. Thus, correlational item analyses are based on 36 cases, except for the state anxiety measures. The regression analysis is computed with the data from 35 participants.

5.1. Item Analysis and Exclusion

For each of the four scales, preliminary total scores were computed. Item analyses took place by computing correlations between each item and the total score of the scale. Items that correlated below 0.3 with the total scale were excluded.

From the presence scale, two items had to be deleted. One referred to perceptions of the own body and caused misunderstandings because of its formulation. The second item asked the following: "Were you able to imagine the virtual room?" Apparently, being able to imagine the VE does not discriminate between high and low presence. Concerning the state anxiety scale, two items had to be deleted. From the acrophobia scale, three items were excluded.

The items analysis of the avoidance scale was more complicated. Because we adopted the original scaling with a Likert-type scale of only 3 points and because of the nonclinical sample, a skewed and asymmetric distribution was observed. Because a high skewness leads to underestimated item-total correlations, the total score of the scale was recategorized into three discrete sections, and the correlations between each item and this discrete score were computed (Steyer & Eid, 1993). Furthermore, the cutoff for the correlations was set to 0.1. On this basis, four items were deleted.

Following this analysis, four scales were constructed. The reliability of the scales was estimated with Cronbach's alpha. The resulting alphas were as follows: acrophobia scale $\alpha = 0.7907$ ($N = 36$; 17 items), avoidance scale $\alpha = 0.7706$ ($N = 36$; 16 items), state anxiety scale $\alpha = 0.8860$ ($N = 35$; 18 items), and presence scale $\alpha = 0.7749$ ($N = 36$; 12 items). Thus, means as total scores were computed for each scale. The means, standard deviations, and correlations are presented in Table 1.

5.2. Correlation and Regression Analysis

Although our participants were a nonclinical sample, some actually experienced fear and tension during the confrontation. Observable reality-checking behavior (such as tapping on the floor before walking over a bridge) and spontaneous reactions to the environment (such as catching virtual balls, which were introduced

Table 1: Means, Standard Deviations, and Correlations of the Observed Variables

	Trait Acrophobia	*Trait Avoidance*	*Presence*	*State Anxiety*
M	1.0507	0.2813	2.0787	1.2032
SD	0.5764	0.2013	0.6146	0.4852
Trait acrophobia	1.0000	—	—	—
Trait avoidance	0.654*	1.0000	—	—
Presence	–0.263	0.011	1.0000	
State anxiety	0.137	–0.148	0.251	1.0000

Note. Possible ranges: trait acrophobia 0–6; trait avoidance 0–2; presence 0–4; state anxiety 0–3.
*$p = .01$ (two-tailed).

in addition to the other virtual stimuli) indicated that experiencing presence was possible in our VE.

The simple correlational analysis shows only a low and nonsignificant correlation between fear of heights and actually experienced fear (r = .137, p > .10) and a nonsignificant correlation between state anxiety and presence (r = .251, p > .10). That means that anxiety is a weak indicator for presence. To test the whole model, a regression analysis was computed. The results are presented in Table 2.

The regression analysis with experienced fear as the dependent variable reveals a picture that is more comprehensive than the simple correlations. Fear of heights as a trait ($\beta = 0.603$, $t = 2.779$, $p < .05$), the related avoidance behavior ($\beta = -0.537$, $t = -2.578$, $p < .05$), and the sense of presence ($\beta = 0.420$, $t = 2.539$, $p < .05$) are all significant factors in the regression equation. The regression equation explains a significant part of the variance, $R^2 = 0.267$, $F(3, 31) = 3.770$, $p < .05$.[1]

However, the interpretation of beta coefficients is difficult because of possible suppression effects. A better interpretation is possible by looking at structure coefficients that can be computed by dividing the simple correlation through the R obtained in the regression equation. The structure coefficient c indicates which part of the predicted variance of the criterion variable (state anxiety) is explained by each predictor alone (Bortz, 1993). The resulting structure coefficients are: $c_{\text{Acrophobia}} = 0.265$; $c_{\text{Avoidance}} = -0.286$; and $c_{\text{Presence}} = 0.485$. These values allow a comparison of the coefficient's relative predictive power.

Interestingly, the negative value of $c_{\text{Avoidance}}$ suggests that participants with an established avoidance behavior find a way to lower their fear in the virtual world.

5.3. Further Exploration of the Presence Scale

The analysis of the presence scale presented earlier was mainly concerned with the homogeneity of the scale in terms of reliability and item-total correlation. However, investigating the structure of the presence scale could contribute to the theoretical investigation. Thus, factor analyses of the 12 selected items were computed. However, it is important to stress that this analysis is explorative in nature because of the small sample size.

The items were factorized using principal component analysis and oblique direct oblimin rotation ($\Delta = 0$). The number of the factors as indicated by the eigenvalues was three, whereas the scree test implied four factors, but these solutions were difficult to interpret. Thus, a two-factor solution was forced. The two factors emerging from this factor analysis can be interpreted as follows: The first factor

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[1]The regression analysis presented here was based on the refined scales, without the items deleted in the item analysis. One might argue that using the full and previously tested scales would be a more conservative method. However, the effects achieved with the full, unchanged scales are very similar to the results presented here; all significant parameters mentioned earlier here also achieve significance when computed with the full scales. The main difference is observable in the multiple correlation R, which decreases from 0.517 to 0.468. The refined scales were chosen in order to adapt the scales to the use of a VE and to the sample used in the study.

Table 2: Results of the Regression Analysis

Model Summary

Model	R	R^2	*Adjusted* R^2	*Standard Error of the Estimate*
1	0.517[a]	0.267	0.196	0.435

ANOVA[b]

Model		*Sum of Squares*	df	*Mean Square*	F	*Significance*
1	Regression	2.140	3	0.713	3.770	0.020[a]
	Residual	5.866	31	0.189		
	Total	8.006	34			

Coefficients[b]

	Unstandardized Coefficients		*Standardized Coefficients*		
Model	B	*Standard Error*	β	t	*Significance*
(Constant)	1.017	0.464		2.193	0.036
Acrophobia	0.505	0.182	0.603	2.779	0.009
Avoidance	–1.286	0.499	–0.537	–2.578	0.015
Presence	0.329	0.129	0.420	2.539	0.016

[a]Predictors: (Constant), presence, avoidance, acrophobia. [b]Dependent variable: state anxiety.

combined items that describe attentional processes such as the absorption by the VE and the remaining attention to the real environment. On the second factor, those items loaded highly which indicated that an environment was constructed from the virtual stimuli (e.g., "I had a sense of being in the virtual room" and "I had a sense of being in a place instead of looking at pictures"). This solution was replicated in a recent study with more than 120 participants, which increases the validity of this solution (Schubert, Regenbrecht, & Friedmann, 1998).

For a further exploration, the factor scores extracted by the factor analysis were entered into a second regression along with acrophobia and avoidance. Thus, the contribution of each factor to the explanation of state anxiety can be investigated. Interestingly, the explained variance marginally increased as indicated by an R of 0.561. Only the second presence factor contributes significantly to the regression equation (b = 0.378, $t = 2.344$, $p = .026$), whereas the first presence factor remains insignificant.

6. DISCUSSION

The results of the statistical analysis confirmed our expectations concerning the role of sense of presence in the development of fear. In summary, we observed that VEs can elicit real emotions. Participants who feared real situations involving heights did also develop anxiety of the virtual cliff. The statistical analysis investigated both the regression coefficients and the structural coefficients. The regression explains a significant part of the anxiety variance; all three predictors are significant. The structural coefficients allow inferences concerning the relative impact of the predictors. From the presented data, we can conclude that presence played the major role in the development of anxiety in the VE. However, it has to be noted that the multiple correlation is not very high.

It is hard to explain this without regarding presence as the primary cause: The anxiety of the virtual cliff of 8 m is an effect of presence. The participants interacted with the virtual world by walking around and looking from different perspectives. Developing presence, they placed themselves in their mental representation of the situation in front of the cliff. Thus, the cliff became important for their evaluation of their situation. Its meaning changed dramatically, resulting in arousal and anxiety. The fear of real heights was transferred on virtual stimuli. It was possible to measure this emergent presence and to show that the resulting anxiety is increased by presence. This illustrates the process of emotional reactions to virtual stimuli. Moreover, it can be seen in a more general sense as an example in which the interaction with a virtual world and its effects can be predicted by measured sense of presence.

In the description of the theoretical model underlying the presence scale, it was stated that the primary component of presence is not taking the virtual world for real but developing a mental representation of the virtual stimuli as one's own environment. The explorative factor analysis of the scale lent some evidence to this idea. Two factors were found, the first one mainly referring to attentional processes, absorption by the virtual stimuli, remaining attention to the real environment and "reality projection" on the virtual world. The second factor combined items that mainly describe the spatial-cognitive process of constructing an environment. Such a division is already visible in the research literature, with some researchers stressing the role of spatial construction, whereas others point to the importance of attentional processes (e.g., Singer & Witmer, 1997). In our study, it was mainly the second factor that predicted the increase of fear, stressing its importance. However, the sample size was fairly low for factor analysis, and the found structure was interpreted only because it was recently replicated in a new study. Further research into the differential effects of facets of presence seems fruitful.

Concerning the investigations at Georgia Tech, it has to be pointed out that fear is not a simple indicator for presence. Rather, presence and trait acrophobia both increase presence. However, one remark concerning the design of the study is necessary. Although we interpret the regression analysis in a causal way, a true demonstration of the causal effect of presence on fear should be shown in an experiment in which presence is manipulated experimentally. We deliberately chose this design in order to demonstrate the usefulness of measuring presence in the process of evaluating design decisions. The emotions observed in our study can be used as validation measures for more general methods of presence assessment. The developed questionnaire seems to be a useful instrument to measure the presence in VEs. Those questionnaires are easy to apply after an immersion and should help in the process of evaluating the effects of virtual worlds in the design process.

It was once again surprising how the participants behaved in the VE. That even our nonclinical patients developed mild anxiety and arousal indicates the potential of VR treatments for phobias, especially because the treatment success is highly dependent on the arousal reached in the confrontation. Additionally, it is interesting that our participants might have found ways to diminish their anxiety. Based on answers given by them in short interviews after the immersion, we think that they managed this partly by consciously decreasing their presence. Unfortunately, we were not able to demonstrate this relation in the statistical data.

In comparison with other VEs, our participants had a lot of floor space to move around. This interaction by walking around, which was provoked by our procedure, seems to support a fast development and elaboration of the mental model of the space. The participants were looking at the virtual room as their environment and knowledge about the real room had to be retested before they relied on it. Thus, they checked the floor by tapping on it before crossing bridges, and they were surprised about themselves and their presence in the room that was clearly virtual. Once again, it becomes clear that the basis of presence is not only some esoteric confusion of VE and real environment, but the construction of a spatial environment that itself is the object of conscious reflection by the participant.

Future studies should seek to describe the different cognitive processes involved in the construction of the spatial model and its relation to the body, as well as the dissociation from the real world by looking at the role of interaction and stimuli configuration in VEs. It seems especially important to analyze cues that signal the combination of real and virtual environment and how such a combination might be supported by the immersive design of the environment.

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