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Research Report

Temporal dynamics in the relation between presence and fear in virtual reality

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ABSTRACT

Virtual reality (VR) is increasingly investigated as a new medium for exposure therapy, but process variables are not well understood. In particular, presence and fear during VR exposure correlate strongly, but the causal relationship between them remains unclear. We assigned 22 female spider-fearful participants randomly to either a stereoscopic (high presence) or a monoscopic (low presence) condition and exposed them repeatedly to a large virtual spider presented on a Powerwall. Presence and fear were assessed on subjective, physiological, and behavioral levels. Fear reactions were stronger and presence ratings were higher in the stereoscopic than the monoscopic condition. Presence in the first exposure trial correlated significantly with fear in the second exposure trial, while fear in the first exposure trial did not correlate significantly with presence in the second exposure trial. For the following exposure trials, correlations between presence and fear were significant in both directions. Limitations of our study include the small sample and the fact that we did not check diagnostic criteria of specific phobia. This is the first study to show temporal dynamics of the relationship between presence and fear. Initially, presence in VR seems to directly influence fear, while over time, presence and fear appear mutually dependent.

1. Introduction

Digital technology has come to dominate our daily lives and is bound to expand in the future, including new forms of human–computer interaction (Lytras & Ordoñez de Pablos, 2011). Increasingly, virtual worlds provide new platforms for communication and interaction, initiating a complex process of mutual adaptation as new environments are created, and users react to them (Zhang et al., 2014; Zhang, Ordoñez de Pablos, & Xu, 2014). The significance of emotion and presence in human–computer interaction has been well documented, for example for therapeutic applications in virtual reality (VR) (Diemer, Alpers, Peperkorn, Shiban, & Mühlberger, 2015), online virtual worlds (Zhang et al., 2014) and product presentation in online shopping (Verhagen, Vonkeman, Feldberg, & Verhagen, 2014). Less is known, however, about how technology creates emotional experiences. This is particularly relevant in mental health applications that directly aim at modifying problematic emotions, like virtual reality exposure therapy.

1.1. Virtual reality exposure therapy

VR has been increasingly investigated in recent years as a medium for exposure therapy. VR exposure therapy provides a range of advantages over *in vivo* exposure (Mühlberger & Pauli, 2011), including greater acceptance by patients (Garcia-Palacios, Botella, Hoffman, & Fabregat, 2007; Garcia-Palacios, Hoffman, See, Tsai, & Botella, 2001). Numerous studies confirm the efficacy of VR-assisted interventions in anxiety disorders (for reviews, see Gregg & Tarrier, 2007; Opris et al., 2012). The viability of anxiety treatment in VR is based on the observation that virtual environments can elicit similar subjective and physiological reactions as real situations (Cornwell, Johnson, Berardi, & Grillon, 2006; Diemer, Mühlberger, Pauli, & Zwanzger, 2014; Mühlberger, Bülthoff, Wiedemann, & Pauli, 2007; Mühlberger, Petrusek, Herrmann, & Pauli, 2005; Villani, Repetto, Cipresso, & Riva, 2012).

Abbreviations: VR, virtual reality; CAVE, cave automatic virtual environment; HMD, head-mounted display; BAT, behavioral approach test; FSQ, Fear of Spiders Questionnaire; SUDS, Subjective Units of Discomfort Scale; BIP, break of presence; IPQ, Igroup Presence Questionnaire.

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1.2. Presence and emotion in VR

It has been suggested that presence, the sense of "being" in the VR world (Botella, Garcia-Palacios, Baños, & Quero, 2009), provides the mediator by which the artificial VR environment may activate "real" emotions (Parsons & Rizzo, 2008; Price, Mehta, Tone, & Anderson, 2011). However, research on the influence of presence on treatment outcome has produced mixed results (Krijn et al., 2004; Price & Anderson, 2007; Price et al., 2011). This might be due to the unclear relationship between presence and fear. Significant correlations between presence and fear have been consistently reported (Hodges, Anderson, Burdea, Hoffman, & Rothbaum, 2011; Price et al., 2011; Regenbrecht, Schubert, & Friedmann, 1998; Riva et al., 2007; Robillard, Bouchard, Fournier, & Renaud, 2003; Schuemie, van der Straaten, Krijn, & van der Mast, 2001), but it remains unclear why they relate. Bouchard, St-Jacques, Robillard, and Renaud (2008) reported data implying a causal influence of fear on presence. Likewise, a study by Baños et al. (2004) highlighted the importance of emotional experience for presence. On the other hand, Michaud, Bouchard, Dumoulin, Zhong, and Renaud (2004) suggested that a manipulation of presence could lead to alterations in experienced fear. However, little empirical work has been published supporting a causal relationship in this direction. Presence can be manipulated by altering the immersive nature of the VR technology. For example, Juan and Perez (2009) reported higher fear and presence ratings in a virtual visual pit presented in a cave automatic virtual environment (CAVE) vs. head-mounted display (HMD). However, presentation via CAVE differs from HMD in many respects (including field of view and navigation) that might affect presence and fear. We chose the system factor stereoscopy to manipulate presence, since stereoscopy can be applied without changing other aspects of the virtual environment. Further, its contribution to the experience of presence is well established (Ijsselsteijn, de Ridder, Freeman, Avons, & Bouwhuis, 2001).

1.3. Aim of this study

The aim of the present study is to test whether a causal influence of presence on fear can be demonstrated in an experimental paradigm that manipulates presence by varying the degree of immersion. This approach should help clarify the relationship between presence and emotion and advance our understanding of how the virtual experience is created in the mind, and how it can be influenced.

We randomly assigned 22 spider-fearful women to a series of exposure trials designed as behavioral approach tests (BATs) in a stereoscopic VR (high presence condition) or a monoscopic VR (low presence condition). Presence and fear were assessed multimodally. We hypothesized that presence would be higher in the stereoscopic condition, and that participants in the stereoscopic condition would show greater behavioral avoidance and more intense subjective and physiological fear reactions.

2. Materials & methods

2.1. Participants

Fifty-nine prospective participants filled in an online scale to assess fear of spiders from 0 (no fear) to 100 (maximum fear). Participants who met the following criteria were invited to the study: fear of spiders rating above 75 (of 100), female and age 18–40 years to enhance sample homogeneity, no history of psychiatric disorders, and no severe physical impairment. Twenty-two female spider-fearful participants (age: 19–38 years; $M = 25.18$; $SD = 5.58$) were included.

2.2. Measures

2.2.1. Psychometric measures

Fear of spiders was assessed with the Fear of Spiders Questionnaire (FSQ) (Szymanski & O'Donohue, 1995), German version (Rinck et al., 2002). During exposure trials, participants were asked to quantify their level of fear on a Subjective Units of Discomfort Scale (SUDS) (Wolpe, 1969) from 0 (no fear) to 100 (maximum fear). Presence was assessed in three ways. Participants rated their feeling of presence on a one-item measure ("To what extent did you feel present in the virtual environment, as if you were really there?") from 0 (no presence) to 100 (maximum presence) after each exposure trial, following the procedure reported by Bouchard et al. (2005). This measure appears more sensitive to acute changes in presence than a questionnaire (Bouchard et al., 2005). Second, at several moments during the experiment, we introduced visual (2 s whiteouts on the Powerwall) and auditory (sounds of footsteps of someone passing by for 30 s) breaks of presence (BIPs) (Brogni, Slater, & Steed, 2003; Garau et al., 2008; Slater, Brogni, & Steed, 2003). Both types of BIPs were presented during the three trials reported here, and during six additional trials that belonged to a similar experiment with the same stereoscopy manipulation. During the experiment reported here, there were two acoustic (one in trial 1 and one in trial 2) and one visual (trial 3) BIP. After the entire laboratory session (comprising both experiments), we asked the participants if they had registered any BIPs, and quantified the number of participants per group that had noticed any visual or acoustic BIPs. Finally, after the experiment, participants filled in the Igroup Presence Questionnaire (IPQ) (Schubert, Friedmann, & Regenbrecht, 2001).

2.2.2. Psychophysiological measures

A 3-lead ECG was recorded at the thoracic wall with Ag/AgCl electrodes (Nessler Medizintechnik, Innsbruck, Austria). Electrodermal activity was recorded at the second phalanx of the index finger and the middle finger with 13/6 mm Ag/AgCl surface-electrodes (MES Medizinelektronik GmbH, Munich, Germany). Physiological signals were measured with a BrainVision V-Amp amplifier (Brain Products, Gilching, Germany), digitalized by a 16-bit analogue-to-digital converter, and saved with a 1000 Hz sampling frequency.

2.3. Fear induction and experimental conditions

Participants were confronted with a large virtual spider (diameter: 35 cm) in a virtual laboratory room on a Powerwall. This room was designed to look like an extension to the actual laboratory room (see Fig. 1). Throughout the experiment, the spider approached the participants in a direct line from the rear wall of the virtual room. Participants had control over the minimum distance between themselves and the spider at all times (BAT procedure; see Section 2.5). In the low presence condition, the VR setup was depicted monoscopically. In the high presence condition, the same VR was presented stereoscopically, thus acquiring additional plasticity. Parameters (convergence and separation of input for each eye) were carefully chosen and tested prior to the experiment to exclude any additional alteration of depth perception between the two conditions.

2.4. Technical equipment

A 3D computer-simulated environment was run on the STEAM-Engine (Valve Corporation; Bellevue, Washington, USA). The virtual laboratory was rendered on a standard Windows PC and displayed on a Powerwall (3-Dims, Frankfurt; width: 325 cm, height: 200 cm). Software drivers for stereoscopic display were activated