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Fear and physiological arousal during a virtual height challenge—effects in patients with acrophobia and healthy controls

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ABSTRACT

Virtual reality (VR) exposure therapy is becoming increasingly established, but the mode of action is not well understood. One potential efficacy factor might be physiological arousal.

To investigate arousal during VR exposure, we exposed 40 patients with acrophobia and 40 matched healthy controls to a VR height challenge and assessed subjective (fear ratings) and physiological (heart rate, skin conductance level, salivary cortisol) fear reactions.

Patients experienced a significant increase of subjective fear, heart rate and skin conductance level. Unexpectedly, controls, who reported no subjective fear, also showed an increase in heart rate and skin conductance. There was no increase in salivary cortisol levels in either group.

Physiological arousal in acrophobic patients, in contrast to subjective fear, might not be stronger than that of controls confronted with height cues in VR, indicating marked discordance across symptom domains. The lack of a cortisol response in a clearly stressful paradigm warrants further study.

1. Introduction

Anxiety disorders are frequent mental disorders (Kessler, Chiu, Demler, Merikangas, & Walters, 2005; Wittchen et al., 2011). Highly effective psychotherapeutical strategies exist, in particular, cognitive-behavioural therapy with exposure techniques (Butler, Chapman, Forman, & Beck, 2006; Choy, Fyer, & Lipsitz, 2007; DeRubeis & Crits-Christoph, 1998; Neuner, 2008). In recent years, research has shown that exposure therapy in virtual reality (VRET) is probably as effective as exposure therapy in vivo for specific phobia (Emmelkamp et al., 2002; Mühlberger, Weik, Pauli, & Wiedemann, 2006; Mühlberger, Wiedemann, & Pauli, 2003). Virtual reality (VR) is attractive as a medium for conducting exposure therapy as it can be conducted in the therapist's office, is safe and confidential, and appears to be more easily accepted by patients (Garcia-Palacios, Botella, Hoffman, & Fabregat, 2007). The efficacy of VRET for specific phobia is confirmed by recent meta-analyses (Opris et al., 2012; Powers & Emmelkamp, 2008). However, little is known about the processes underlying its efficacy.

1.1. Psychophysiological arousal during exposure therapy

One process that is often considered central to exposure therapy is psychophysiological arousal (Foa & Kozak, 1986). Foa and Kozak (1986) and Foa and McNally (1996) propose in their emotional processing theory (EPT) that psychophysiological arousal is necessary for overcoming dysfunctional fear and anxiety. According to EPT, pathological fear is represented in the brain in a memory network (the fear structure) that links the emotional, cognitive, behavioral and physiological response patterns and the feared stimuli and/or situations. EPT postulates that a comprehensive activation of its components is a precondition for changing the fear structure. Psychophysiological arousal indicates the activation of the fear structure, while habituation during exposure therapy is seen as an indicator of successful changes in the memory network (Foa & Kozak, 1986).

Abbreviations: ACRO/AVOI, acrophobia questionnaire; ASI-3, anxiety sensitivity index 3; bpm, beats per minute; EDA, electrodermal activity; EPT, emotional processing theory; HMD, head-mounted display; HR, heart rate; IPQ, igroup presence questionnaire; SCL, skin conductance level; SSQ, simulator sickness questionnaire; SUDS, subjective units of discomfort scale; VR, virtual reality; VRET, virtual reality exposure therapy.

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While the evidence for EPT is mixed, encouraging patients to experience (rather than avoid) fear and its symptoms during exposure therapy is common practice (Craske et al., 2008). It has been argued that acceptance of unpleasant emotions and sensations might be important for exposure therapy (Craske et al., 2008). Thus, even though EPT has not been confirmed, physiological arousal during exposure therapy is still considered an important component of this form of anxiety treatment. Strong psychophysiological arousal has been documented during in vivo exposure for specific phobia, including driving phobia (Alpers, Wilhelm, & Roth, 2005), flying phobia (Wilhelm & Roth, 1998), claustrophobia (Alpers & Sell, 2008), and animal phobias (Nesse et al., 1985).

So far, only a limited number of studies have investigated physiological arousal during exposure in VR (for a review, see Diemer, Mühlberger, Pauli, & Zwanzger, 2014). The most frequently used physiological measures are heart rate (HR) and parameters of electrodermal activity, most commonly skin conductance level (SCL). A number of studies have shown significant HR reactions of phobic and fearful participants in fear-related VR environments (Cornwell, Johnson, Berardi, & Grillon, 2006; Mühlberger, Bülthoff, Wiedemann, & Pauli, 2007; Mühlberger, Petrusek, Herrmann, & Pauli, 2005). Overall, however, the evidence for an impact of VR challenges on HR is mixed, but there is convincing evidence that VR exposure leads to significant increases in SCL (Diemer et al., 2014).

In the case of acrophobia, VR studies so far have focused on height fearful participants and height effects on healthy volunteers. For example, Wilhelm et al. (2005) found significant increases of HR and SCL in height fearful as well as healthy participants during a VR elevator ride; physiological arousal differed between groups for SCL, but not for HR. Physiological arousal as a response to height challenges in healthy participants has been reported for height simulations in VR (Meehan, Insko, Whitton, & Brooks, 2002) as well as real heights (Simeonov, Hsiao, Dotson, & Ammons, 2005). Interestingly, Simeonov et al. (2005) found a significant increase in SCL, but not in HR, during VR height exposure, while both parameters were significantly elevated during in vivo height exposure. Unfortunately, no height fearful or phobic participants were assessed in this study. Therefore, it is not clear so far to what extent VR height exposure is capable of eliciting psychophysiological arousal in patients suffering from acrophobia.

Another, not yet fully understood physiological parameter during exposure to phobic situations is cortisol level. So far, few studies have investigated cortisol response to in vivo phobic stimuli or situations. While a robust cortisol increase has been reported during driving in driving phobia (Alpers, Abelson, Wilhelm, & Roth, 2003), and patients with agoraphobia were found to show greater release of salivary cortisol during in vivo exposure than during a control therapy session without exposure (Schumacher et al., 2014), studies of patients with social phobia did not find evidence for a generally increased cortisol response to the Trier Social Stress Test (TSST), a potent psychosocial stressor (Furlan, DeMartinis, Schweizer, Rickels, & Lucki, 2001; Klumbies, Braeuer, Hoyer, & Kirschbaum, 2014). In VR exposure, salivary cortisol has so far been mostly investigated in paradigms involving social stress, like the TSST (Diemer et al., 2014; Jönsson et al., 2010; Kelly, Matheson, Martinez, Merali, & Anisman, 2007). These studies report a significant increase of cortisol in response to a VR TSST, indicating that VR scenarios may induce an endocrine response in terms of salivary cortisol increase. However, few studies have investigated whether cortisol increases during exposure to phobic stimuli in VR.

Although subjective fear, physiological arousal and avoidance have long been documented as the typical correlates of fear, the extent to which different indicators of fear covary is unclear. Studies have reported discordance (Rachman & Hodgson, 1974), concordance (Sartory, Rachman, & Grey, 1977), or mixed results (Matias & Turner, 1986). Apparently, the degree of concordance observed depends on aspects of study design and the way covariance is assessed. For example, Alpers and Sell (2008) found evidence for high synchrony (i.e., within-subject covariance) of arousal and fear in the absence of clear concordance (i.e., between-subject covariance). Despite the limited evidence for concordance, studies assessing differences in physiological reactivity between phobic patients and healthy controls during in vivo exposure have typically found clear and significant differences between the groups (Alpers et al., 2005; Wilhelm & Roth, 1998). In VR, significant differences between phobic/fearful participants and healthy controls have been reported in some studies (Mühlberger et al., 2007, 2005), but results seem overall less clear than in in vivo studies (cf. Diemer et al., 2014, for a review).

1.2. Aim of the present study

The aim of the present study was to test whether a height challenge in VR elicits a comprehensive fear reaction in patients suffering from acrophobia including subjective and physiological (HR, SCL, salivary cortisol) fear measures, and to compare the reaction of patients to that of matched healthy controls. Acrophobia was chosen as VRET for this anxiety disorder is especially well documented, and known to be effective (Emmelkamp et al., 2002; Meyerbröker & Emmelkamp, 2010). We hypothesized that patients with acrophobia would show significant fear reactions on all parameters (compared to baseline), while healthy controls were not expected to show fear on any measure. As presence, i.e., the sense of actually being in the VR simulation, is an important aspect of a VR experience with close links to emotion (Diemer, Alpers, Peperkorn, Shiban, & Mühlberger, 2015; Peperkorn, Diemer, & Mühlberger, 2015), presence was assessed in both groups.

2. Materials and methods

2.1. Participants

Forty patients with acrophobia and 40 matched healthy controls participated in this study. Patients with acrophobia and healthy controls were recruited with advertisements in local media. For inclusion in the study, patients had to fulfil diagnostic criteria of specific phobia (heights) according to DSM-IV-TR (American Psychiatric Association, 2000). Exclusion criteria relevant for patients were acute mood or substance use disorder, history of psychotic disorder, or acute suicidal ideation; epilepsy or other disease of the central nervous system; migraine; concurrent use of psychoactive drugs or current psychotherapy; history of heart disease; and pregnancy. Additionally, controls were included only if they had no history of any mental disorder themselves or in their first-degree relatives. Inclusion and exclusion criteria were assessed with the Mini neuropsychiatric interview (MINI) (Ackenheil, Stotz-Ingenlath, Dietz-Bauer, & Vossen, 1999; Lecrubier et al., 1997; Sheehan, Janavs et al., 1998; Sheehan, Lecrubier et al., 1998) and by clinical interview.

2.2. Measures

2.2.1. Questionnaires

At baseline, participants filled in a demographic questionnaire and the German version (Kemper, Ziegler, & Taylor, 2009) of the Anxiety Sensitivity Index-3 (ASI-3) (Taylor et al., 2007). Anxiety sensitivity describes the tendency to view anxiety and its symptoms as threatening, and is considered a risk factor for anxiety disorders (Schmidt, Zvolensky, & Maner, 2006). We included the ASI-3 for the characterization of our study sample. The ASI-3 contains 18 items (each scored on a 5-point Likert scale), forming