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ORIGINAL ARTICLE

Cognitive Processing and Regulation Modulates Analogue Trauma Symptoms in a Virtual Reality Paradigm

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Abstract
To date, few studies have examined stress responses during or shortly after potentially traumatic events in real-time. In this study, a prospective Virtual Reality analogue trauma paradigm was used to assess peri- and post-traumatic stress responses in healthy individuals ($N=80$). Here we compared a range of peri-traumatic psychophysiological responses following analogue trauma to a control condition. Furthermore, we aimed to identify essential regulatory mechanisms in response to an analogue trauma and their effects on subsequent analogue trauma symptoms. Therefore, we examined the impact of subjective and physiological emotional responses, cognitive processing, cognitive regulation and appraisal as well as flexible emotion regulation on analogue trauma symptoms. Results of the hierarchical multiple regression analyses revealed that cognitive processing as well as cognitive regulation and appraisal predicted analogue trauma symptoms beyond psychophysiological responses, while flexible emotion regulation was uniquely predictive only directly afterwards. The findings provide evidence that flexible emotion regulation might be in particular protective directly after trauma exposure and highlight the general importance of peri- and post-traumatic cognitive factors in the development and maintenance of stress-associated psychopathology, thereby supporting cognitive models of PTSD.

Keywords Stress · Cognitive processing · Emotional response · Cognitive regulation · Appraisals · Emotion regulation · Intrusive memories · Analogue trauma · Virtual Reality

Over their lifetime, many people will witness or experience a traumatic event, however only a fraction develop subsequent stress-associated psychopathology or mental disorders such as posttraumatic stress disorder (PTSD) (Bonanno et al. 2011b). Peri- and post-traumatic factors have been found to explain the differential development of PTSD in clinical (Brewin et al. 2000; Ozer et al. 2003) and experimental studies (Ripley et al. 2017). Cognitive PTSD models further reflect the importance of peri- and post-traumatic responses to trauma and trauma-related symptoms (Ehlers and Clark 2000; Laposa and Rector 2012). Other memory-based models such as the mnemonic model of PTSD also propose that a dysfunctional memory of a traumatic event, instead of the event per se, leads to PTSD (Rubin et al. 2008). A recent development of this approach comprises an exposure-dependent model of PTSD indicating the importance of dynamically interacting symptoms of intrusions and anxious arousal for the course of PTSD development and maintenance (Solberg et al. 2016). Furthermore, sufficient regulation of the emotions elicited in response to a traumatic event has been shown to be critical (e.g. LeBlanc et al. 2011). However, it is still not clear to what extent cognitive processing, cognitive regulation and appraisal as well as emotion regulation affect post-traumatic symptoms beyond the impact of the psychophysiological response. Therefore, in the current study we aimed to investigate the role of subjective and physiological emotional as well as cognitive variables for the prediction of analogue trauma symptoms, which was rarely performed in previous research due to different research traditions. Thus, our study may provide a more comprehensive perspective about the impact of cognitive variables in the development of analogue trauma symptoms, while controlling for emotional subjective and physiological responses.

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In particular, an intense peri-traumatic psychophysiological emotional response has been found to increase the risk of developing PTSD in clinical samples (Bryant et al. 2000; Ozer et al. 2003) and trauma symptoms in experimental studies (Clark et al. 2015; Regambal and Alden 2009; Ripley et al. 2017). This response typically includes fear, helplessness, or horror (Ozer et al. 2003) as well as physiological arousal indicated by increased heart rate (HR) and skin conductance levels (SCL) (Brunet et al. 2001; Bryant et al. 2000; Hinrichs et al. 2018; Ripley et al. 2017; Shalev et al. 1998; Weidmann et al. 2009). Intense peri-traumatic emotions have been shown to particularly impair cognitive stress processing, resulting in intrusions and disorganised trauma memories (Ehlers and Clark 2000; Halligan et al. 2002; Regambal and Alden 2009; Weidmann et al. 2009). Since previous research has focused mainly on anxiety symptoms, we aimed to also investigate crucial peri-traumatic emotions such as shame, guilt (Aakvaag et al. 2014, 2016; Cunningham et al. 2017; Lee et al. 2001; Leskela et al. 2002; Ozer et al. 2003), anger and sadness (Bovin and Marx 2011). In addition, levels of subjective arousal and stress (Boden et al. 2015), as well as the perceived ability to act (Benight and Bandura 2004; Lazarus and Folkman 1984) was found as important in actively coping with stress and for the development of psychopathological symptoms.

Another important peri-traumatic factor is the cognitive processing of a stressful event (Regambal and Alden 2009). Both data-driven and a lack of self-referent processing during a traumatic event have been associated with higher frequencies of intrusive memories and more distress regarding intrusive memories in experimental analogue studies (Halligan et al. 2002; Laposa and Rector 2012; Logan and O'Kearney 2012). Furthermore, both peri-traumatic data-driven and a lack of self-referent processing were associated with the development of PTSD symptoms in clinical studies (e.g. Halligan et al. 2003). Data driven as opposed to conceptual processing refers to processing by focusing on sensory and perceptual details, while a lack of self-referent processing refers to a decreased ability to processes an experience in relation to the self and autobiographical information (Halligan et al. 2003). Intrusive memories, as involuntary recollections of the stressful event, are rather common in the immediate aftermath of a traumatic event, while persisting intrusions are considered a hallmark symptom of PTSD (American Psychiatric Association 2013). Furthermore, mental occupation, referring to the amount of time processing the stressful event and related symptoms (Matthieu et al. 2007) and worry, as cognitive strategy to anticipate possible future danger (Mathews 1990), has been found to be important in the aftermath of traumatic events.

Post-traumatic maladaptive cognitive regulation and appraisals of traumatic events (Meiser-Stedman et al. 2009) or trauma-associated symptoms such as intrusions (Halligan et al. 2003) have predicted PTSD and are also included as a separate diagnostic criteria of trauma-related negative changes in mood and cognitions in the DSM-5 (American Psychiatric Association 2013). Cognitive models of PTSD (e.g. Ehlers and Clark 2000) highlight the importance of maladaptive cognitions and appraisals in the development and maintenance of PTSD symptoms by contributing to a sense of ongoing threat and avoidance of trauma-related stimuli (Dunmore et al. 2001; Halligan et al. 2003). In particular, negative cognitions related to the self, such as self-blame, have been found to be strongly associated with the severity of PTSD symptoms (Hansen et al. 2014). In addition, the perceived centrality of an experienced event regarding the own identity seems to be related to PTSD symptom development (Berntsen and Rubin 2006; Blix et al. 2014; Brown et al. 2010). Furthermore, rumination in response to a traumatic event can function as a strategy to avoid trauma-related emotions and thereby prevent trauma memory elaboration and integration. In particular, rumination about trauma-associated stimuli has been found to be related to PTSD symptoms (Michael et al. 2007). In contrast, effective regulation of intense emotions has been found to be associated with mental health (Bonanno et al. 2004; LeBlanc et al. 2011). In contrary to research aiming to identify single adaptive or maladaptive strategies, recently it has been shown that the flexible application of different strategies depending on the context might be most adaptive in coping with traumatic stress (Aldao et al. 2015; Bonanno et al. 2011a; Seligowski et al. 2015). Since post-traumatic insufficient stress regulation can further lead to poor adjustment in the aftermath of traumatic events (Rizvi et al. 2008), effective emotion regulation seems essential.

To investigate peri- and post-traumatic factors and prevent bias-related problems of retrospective assessment we used a real-time experimental stress induction via a multisensory Virtual Reality (VR) analogue trauma compared to a VR neutral control condition. Previous research has shown that VR can elicit similar stress responses and intrusive memories as viewing trauma films (Becker-Asano et al. 2011; Cuperus et al. 2017; Dibbets and Schulte-Ostermann 2015), and higher emotional stress responses than watching aversive pictures (Courtney et al. 2010) or a respective stressful script-driven imagery procedure (Schweizer et al. 2018). As an advanced method in prospective analogue designs, the VR paradigm enable additional first-person perspectives and person–environment interaction in a multi-sensory simulation using novel olfactory stimuli and provides a new experimental psychopathology model to study trauma exposure and peri-and post-traumatic processes in a standardised laboratory setting (Schweizer et al. 2017, 2018).

In the current study, we aimed to gain a deeper understanding of the important regulatory mechanisms in response to an analogue trauma, which influence subsequent analogue trauma symptoms in a real-time investigation. In particular, the current study aimed to test the assumption of the cognitive model of PTSD (Ehlers and Clark 2000) that trauma-related maladaptive cognitions and appraisals are critical for the development of subsequent analogue trauma symptoms taking into account the psychophysiological stress response. Furthermore, we investigated whether flexible emotion regulation mitigates analogue trauma symptoms. Therefore, we focused on intrusive memories, related worry and mental occupation as earlier (Mc Farlane 2000; Solberg et al. 2016) and on intrusion, hyperarousal, and avoidance as later analogue trauma symptoms (Hansen et al. 2014; Mc Farlane 2000; Solberg et al. 2016).

As first outcome, we expected higher peri-traumatic psychophysiological reactivity for all subjective and peripheral-physiological parameters (HR, SCL) of the stress response in the VR analogue compared to a VR neutral condition using a repeated measure within-subjects design. As second and main outcome, we hypothesized that (1) peri-traumatic psychophysiological responses predict subsequent analogue trauma symptoms after 1 day (IMQ) and 1 week (IES-R) and that (2) dysfunctional cognitive processing (data-driven, lack of self-referent processing) and maladaptive cognitive regulation and appraisal (self-blame, rumination) as well as less flexible emotion regulation predict subsequent analogue trauma symptoms after 1 day (IMQ) and 1 week (IES-R) above and beyond peri-traumatic psychophysiological stress responses.

Method

Participants

Participants were recruited online and at the University of Freiburg. A priori power analysis revealed a sample size of 80 participants would be required to detect a medium-sized effect in a hierarchical multiple regression analysis with seven predictors ($1-\beta=.80$, $\alpha=.05$) (Soper 2018). Exclusion criteria were a prior traumatic experience (referring to a study from Foa et al. 1997), a self-reported diagnosis of a mental disorder or current use of medication that affects emotions. After screening 102 individuals, and excluding a further eight participants due to incomplete questionnaire data sets and one participant due to cyber sickness during the experiment and re-recruiting one participant, 80 participants were included in the study (63 women, 17 men). The mean age was 22 years ($M=21.73$; $SD=2.32$), and education level was high (100% qualification for university entrance). Informed consent was obtained from all individual participants included in the study. The study was conducted according to the Declaration of Helsinki and approved by the Ethics Commission of the University of Freiburg.

Procedure

After receiving information about the study, participants provided written informed consent and completed the baseline questionnaires. Baseline levels of emotional physiological parameters and subjective responses (resting state) were assessed during (SCL, HR) and after (subjective anxiety, arousal, guilt, shame, anger, sadness, stress, helplessness, ability to act) watching a 5 min non-arousing film clip of landscapes.

Participants received VR training before being exposed to first the neutral and then the analogue trauma VR conditions. Additional 5 min resting state phases between training and neutral condition as well as between neutral and analogue trauma condition were used to avoid potential carry-over effects. The VR situation was presented in a standardised manner until the start of the emergency situation. To allow for the most realistic simulation, no instructions about potential coping options in the emergency situation were provided. To further induce a high degree of realness and immersion in the VR analogue trauma (Bordnick et al. 2005; Munyan et al. 2016), a smell of smoke was distributed (Wilhelm Perfumes, Zürich, Switzerland) by the experimenter. After each condition, subjective anxiety, arousal, guilt, shame, anger, sadness, stress, helplessness, and the ability to act was measured, while SCL and HR was recorded during the entire experiment under constant temperature control (22 °C). Directly after the analogue trauma, cognitive processing (CPQ), cognitive emotion regulation and appraisal (CERQ) and emotion regulation flexibility (PACT) were examined. After the experiment, participants were asked to answer scenario-specific questions about VR paradigm specific (e.g. presence) and control (e.g. compliance, attention) parameters. Finally, early analogue trauma symptoms of intrusive memories, related worry and mental occupation were assessed the following day (IMQ), and later analogue trauma symptoms of intrusive memories, hyperarousal and avoidance were assessed 1 week later (IES-R). At the end of the study participants were debriefed.

Materials

Experimental and Control Stimuli

Both VR scenarios were based on a modification of a video-game simulator (Valve's Source Engine). They were visually presented in 3-D via a Head Mounted Display consisting of two colour displays (HMD; Type TriVisio VR Vision). A Calibri tracker in the HMD transmitted participants' head movements to record changes in the visual field within VR. Movements within the VR were performed via joystick (Type Thrustmaster T.16000M). Before the VR scenarios, participants received VR training comprising tasks to familiarise participants with the handling of the technical devices and the orientation in the virtual scenario. The game engine automatically registered the time within the VR scenarios.

VR Neutral Condition A situation in an underground parking lot without any negative events was simulated visually (via 3-D) and auditorily (via headphones) presented as a neutral non-stressful control condition in the virtual scenario. Participants received the instruction to go to their car, which was temporarily blocked by an uploading pickup truck. While waiting, participants could search for and contact the driver.

VR Analogue Trauma Condition An underground parking lot with an emergency situation was presented as the analogue trauma. The multi-sensory simulation comprised visual (via 3-D), auditory (via headphones) and olfactory (via smoke vaporisation by a ventilator) presentation (Bordnick et al. 2005; Munyan et al. 2016). During the emergency scenario, participants were instructed to go to their car, and a loud detonation followed by fading lights and the smell of smoke was presented before they reached the car. Subsequently, a burning car and an injured man who was crying for help were displayed in the virtual scenario. The presentation of auditory coughing sounds as well as olfactory and visual smoke was used for the induction of psychophysiological threat. The VR scenario was terminated once participants left the parking lot.

Baseline Characteristics

Socio-demographic characteristics and experience with computer games (1 = *not at all* to 11 = *extreme*) and as a rescue worker (yes/no) were assessed prior to the experiment.

Psychological distress during the last 7 days concerning overall psychopathology was measured with the Global Severity Index (GSI) of the 53-item Brief Symptom Inventory (BSI; Franke 2000) on a 5-point-scale (0 = *not at all* to 4 = *extreme*). The GSI has shown a high internal consistency of $\alpha = .95$ (Franke 2000).

Current depressive symptoms were examined using the 20-item simplified Beck Depression-Inventory (BDI-S; Beck et al. 1996; Schmitt and Maes 2000) on a 6-point scale (from 0 = *never* to 5 = *almost always*) with a clinical cut-off value of 35 (Schmitt et al. 2006). The BDI-S has demonstrated a very good reliability of $\alpha = .93$ (Schmitt et al. 2003).

Anxiety symptoms within the last week were assessed by the 21-item Beck Anxiety Inventory (BAI; Beck et al. 1988; Margraf and Ehlers 2007) on a 4-point scale (0 = *not at all* to 3 = *extreme*). Internal consistency in non-clinical samples was $\alpha = .76$–.94 (Margraf and Ehlers 2007).

Manipulation Check

To ensure similar exposure times between the analogue trauma and neutral conditions, the duration within both VR conditions were recorded from the game engine. We investigated whether the VR analogue trauma elicited a significantly greater subjective 0–100 on a visual analogue scale (VAS) (Lesage et al. 2012) and physiological (HR, SCL) stress response than the neutral VR condition. As attentional control task, we asked participants for correct detail recognition regarding the colour of a ticket machine to control for sufficient attention during the VR analogue trauma. Furthermore, participants were asked to rate their level of compliance in fully participating in the experiment (1 = *not at all* to 6 = *extreme*).

VR Specific Variables

The sense of presence in VR was examined by the 14-item IGroup Presence Questionnaire (IPQ; Schubert et al. 2001) via the subscales sense of being there, spatial/physical presence, involvement, and experienced realism on a 7-point scale (0 = *not at all* to 6 = *very much*). The IPQ has demonstrated an internal consistency of $\alpha = 0.63$–0.78 (Schubert 2003).

Participants were asked further six scenario-specific questions about their experience with the cover story, the injured person, the perception of the smell of smoke, and the occurrence of cyber sickness in the analogue trauma condition.

Peri- and Post-Traumatic Questionnaires

State anxiety was investigated by the 20-item state subscale of the State-Trait Anxiety Inventory (STAI-S; Laux et al. 1981; Spielberger et al. 1983) on a 4-point scale (1 = *not at all* to 4 = *very much*). The STAI-S has shown internal consistencies of $\alpha > .90$ (Laux et al. 1981).

Peri-traumatic responses such as helplessness, shame, guilt, anger, sadness and ability to act were assessed on an 11-point Likert scale (0 = *not at all* to 10 = *very strong*) (Leung 2011). Stress was rated using a 0–100 VAS (Lesage et al. 2012).

Cognitive processing of stress was assessed by the 25-item Cognitive Processing Questionnaire (CPQ; Ehlers et al. 1998; Ehlers 2002; Halligan et al. 2002) with the subscales data-driven processing, dissociation and lack of self-referent processing on a 5-point-scale (0 = *not at all* to 4 = *very strong*). In the current study we used only the data-driven and self-referent processing scales. Internal consistency of the CPQ was $\alpha > .70$ (Ehlers et al. 1998; Halligan et al. 2002).

Cognitive emotion regulation strategies/appraisal were examined on 5-point scales (1 = *almost never* to 5 = *almost* *always*) by the 36-item Cognitive Emotion Regulation Questionnaire (CERQ; Garnefski and Kraaij 2007). This instrument consists of nine subscales, with five classified as adaptive (acceptance, refocus on planning, positive refocusing, positive reappraisal, putting into perspective) and four as maladaptive (self-blame, blaming others, rumination, catastrophizing). In the current study we used the validated 27-item German version of the CERQ (Loch et al. 2011) and assessed only the subscales self-blame and rumination. Internal consistency ranged between α = .75 and .87 (Garnefski and Kraaij 2007).

Emotion regulation flexibility was assessed using the 20-item Perceived Ability to Cope with Trauma Scale (PACT; Bonanno et al. 2011a) on a 7-point scale (1 = *not at all able* to 7 = *extremely able*). The PACT consists of the two basic dimensions of forward focused (disengagement from the traumatic event) and trauma-focused (engagement with the traumatic event) coping. A coping flexibility score ranging from 0 to 1 was calculated by the formula $F = [(2 \times S + 1)/(S + L + 2)]$, using the means of the two coping dimensions (S = smaller mean, L = larger mean). A higher score indicates greater flexibility. Internal consistencies were α = .79–.85 (Bonanno et al. 2011a).

Analogue Trauma Symptoms After 1 Day Involuntary intrusive memories, related worry and mental occupation 1 day after the analogue trauma were assessed by the modified 10-item Intrusive Memory Questionnaire (IMQ; Michael and Ehlers 2007). The IMQ captures the frequency (absolute number of occurrence) of intrusive memories and related worry ("0" = *not present* to "100" = *most extreme*) regarding visual images, sounds/smells and thoughts as well as the period of mental occupation with the experienced event and related symptoms (0–100%). We did not include items regarding the temporal appearance of intrusive memories in our study. Internal consistency of the IMQ in the current study was α = .76.

Analogue Trauma Symptoms After 1 Week Post-traumatic stress symptoms such as intrusive memories, hyperarousal, and avoidance after 1 week following the analogue trauma were measured with the 22-item Impact of Event Scale-Revised (IES-R; Maercker and Schützwohl 1998; Weiss and Marmar 1997) on a 4-point scale (0 = *not at all* to 4 = *often*). The IES-R displayed adequate internal consistencies, at α = .71–.90 (Maercker and Schützwohl 1998).

Acquisition and Analysis of the Physiological Data

As objective biological markers we recorded SCL and HR, both indicating emotional arousal (Boucsein 2012; Kreibig 2010). While SCL is strongly related to sympathetic activity and emotional processes (Critchley 2002) and to the declarative memory (Soeter and Kindt 2013), HR is related to sympathetic and parasympathetic activity as well (Berntson et al. 1994; Cacioppo et al. 1994). Data recording was performed at 400 Hz via Varioport II Systems (Becker Meditec, Karlsruhe, Germany). SCL was assessed via a constant current flow voltage of 0.5 V over two 11 mmAg/AgCl electrodes placed on the index and middle fingers of the non-dominant immobilised hand at a sampling rate of 125 Hz. A 1 Hz low-pass filter was used to smooth the SCL raw signals. A 3-lead wire (Einthoven's Triangle) electrocardiogram recorded the HR at a sampling rate of 400 Hz. During conduction, SCL and HR were constantly controlled. Participants were monitored and instructed to avoid movements during the experiment. Analysis and artefact correction of SCL and HR were performed at 1 min intervals and averaged over 3 min per phase using ANSLAB (Blechert et al. 2016; Wilhelm and Peyk 2005).

Data Analysis

Data analyses were performed using SPSS version 25.0. Reactivity scores were calculated by subtracting the baseline value from the condition value for psychophysiological responses and ability to act. To enhance the reliability of the outcome score and address the lack of specificity of single measures (Hinz et al. 2000; Jänig and Häbler 2000), composite scores of both all peri-traumatic subjective emotional responses (anxiety, guilt, shame, anger, sadness, helplessness) as well as physiological parameters (HR, SCL) was calculated using z-standardisation (in order to make different answer rating scales comparable and avoiding multicollinearity) and used as a predictor in the regression analysis. Furthermore, a sum score was calculated of the data driven and self-referential subscales of the CPQ. We checked for multivariate outliers (< 3 SD) and assumptions of statistical analysis (Hair et al. 2010).

Paired sample *t* tests were conducted to compare psycho-physiological reactivity between the analogue trauma and neutral conditions in a repeated measure design, with experimental condition (VR neutral, VR analogue trauma) as within-subjects factor. Paired sample *t* tests were also conducted to investigate possible differences between exposure times of these conditions.

Associations between study variables were explored using Pearson product-moment correlation. Hierarchical multiple regression analyses were conducted to test the extent to which peri-traumatic cognitive processing, post-traumatic cognitive regulation and appraisal as well as post-traumatic flexible emotion regulation were uniquely able to predict (a) analogue trauma symptoms after 1 day (IMQ) and (b) analogue trauma symptoms 1 week (IES-R) after the VR analogue trauma, over and above peri-traumatic psychophysiological emotional response and controlled for pre-traumatic depression. Predictors were chosen based on previous research and entered according to their occurrence in time in a series of steps to build hierarchical models. Since previous studies suggest that depressive symptoms are associated with analogue trauma symptoms (Laposa and Alden 2008; Ozer et al. 2003), the BDI-S score was entered at step one to control for pre-existing depression. The peri-traumatic psychophysiological response to the VR analogue trauma was entered at step two, cognitive processing during the analogue trauma at step three, post-traumatic cognitive regulation and appraisal at step four and post-traumatic flexible emotion regulation at Step 5. As recommended for multiple regression models, all correlation coefficients between study variables were $r < 0.9$, tolerance values > 0.1 and variance inflation factor (VIF) values < 10, indicating no multicollinearity (Hair et al. 2010). $R^2\Delta$ was reported for the R^2 change from the previous step with all predictors included and beta for the importance of predictors.

For all analyses a significance level of $\alpha = .05$ was chosen for two-tailed conservative hypothesis testing. Effect sizes were reported for d/d_z (small = 0.2; middle = 0.5; large = 0.8) and f^2 (small = 0.02; middle = 0.15; large = 0.35) (Cohen 1988).

Results

Baseline Characteristics

Our sample showed non-clinical levels of global psychological distress (BSI-GSI; $M = 0.40$; $SD = 0.21$), depression (BDI-S; $M = 20.35$; $SD = 8.85$) and anxiety (BAI; $M = 3.67$; $SD = 2.30$). Participants' experience with computer games ($M = 1.62$; $SD = 1.28$) and as rescue workers ($n = 2$; 2.5%) was low.

Manipulation Check

The VR analogue trauma elicited significantly higher subjective and physiological (SCL, HR) stress responses than the neutral VR condition (see Table 1), indicating a successful stress versus no-stress induction. Exposure time within the analogue trauma ($M = 5.01$, $SD = 1.70$) and neutral ($M = 5.18$, $SD = 0.93$) conditions was not significantly different ($t(79) = .86$, $p = .392$). Participants showed sufficient attention during the analogue trauma condition with a high rate of correct detail recognition (94%) in the attentional control task. Self-reported compliance was high ($M = 5.09$, $SD = 0.95$).

VR Specific Variables

As shown in Table 2, the cover story was rated as very plausible. The analogue trauma situation was perceived as mainly realistic and participants were highly involved. Most of the participants saw and wanted to rescue the injured person. Most of the participants perceived the smell of smoke within VR and rated it as highly beneficial in facilitating the immersion in VR. Participants reported minimal degrees of cyber sickness (see Table 2 for details).

Descriptive Statistics and Associations of Key Study Variables

As shown in Table 3, participants showed in particular relatively high levels of peri-traumatic anxiety and helplessness and slightly higher levels of data-driven than lack of self-referential processing. Concerning cognitive regulation and appraisal, participants displayed more rumination than self-blame. Furthermore, participants showed relatively frequent

Table 1 Differences in psychophysiological stress reactivity between the VR analogue trauma and neutral conditions

Reactivity	Condition		Test statistic	p	ES d_z
	VR neutral scenario M (SD)	VR analogue trauma M (SD)			
STAI-S	4.44 (8.24)	19.33 (10.97)	$t(79) = 12.52$	< .001	1.40
Guilt	0.09 (1.17)	1.69 (2.42)	$t(79) = 6.40$	< .001	0.72
Shame	0.19 (1.32)	1.18 (2.09)	$t(79) = 3.82$	< .001	0.43
Anger	0.38 (0.96)	1.49 (1.96)	$t(79) = 5.14$	< .001	0.58
Sadness	− 0.33 (0.93)	0.96 (2.19)	$t(79) = 5.61$	< .001	0.63
Helplessness	0.48 (1.21)	5.17 (2.11)	$t(79) = 20.29$	< .001	2.27
Ability to act	− 0.05 (2.09)	− 1.54 (2.72)	$t(79) = 5.18$	< .001	0.58
Stress	5.45 (6.81)	46.31 (17.12)	$t(79) = 21.64$	< .001	2.42
Arousal	0.01 (1.68)	4.42 (2.40)	$t(79) = 18.81$	< .001	2.10
HR	1.19 (4.17)	10.29 (7.86)	$t(79) = 9.74$	< .001	1.09
SCL	0.075 (0.337)	0.341 (0.298)	$t(79) = 5.67$	< .001	0.63

STAI-S State State-Trait Anxiety Inventory-State version, *HR* Heart Rate, *SCL* Skin Conductance Level

Table 2 Scenario-specific variables during the VR analogue trauma stress induction

	M (*SD*)
Plausibility of the cover story: *M* (*SD*)[a]	4.98 (1.21)
IPQ: *M* (*SD*)[b]	
Sense of being there	4.49 (1.35)
Spatial presence	4.20 (0.71)
Involvement	4.09 (0.50)
Experienced realism	4.03 (0.74)
Degree of cyber sickness: *M* (*SD*)[a]	1.32 (0.61)
Perception of smell of smoke: *M* (*SD*)[a]	5.69 (0.72)
Immersion facilitated by smell of smoke: *M* (*SD*)[c]	1.74 (0.59)
Intention to rescue the injured person: *M* (*SD*) [a]	4.61 (2.07)
Failure to notice the injured person *N* (%)	6 (7.5%)

IPQ IGroup Presence Questionnaire

[a]Likert-scale from 1 = *not at all* to − 6 = *extreme*

[b]Likert-scale from 0 = *not at all* to 6 = *extreme*

[c]Likert-scale from − 2 = *not at all* to + 2 = *very much* (including "0")

intrusive memories following VR analogue trauma after 1 day.

Peri-traumatic Psychophysiological Emotional Reactivity

In accordance with our predictions, all parameters of subjective and physiological emotional reactivity as well as ability to act reactivity were significantly higher in the VR analogue trauma condition than in the neutral condition (Table 1).

Post-Traumatic Analogue Trauma Symptoms

Analogue Trauma Symptoms After 1 Day (IMQ)

Depression as a control parameter (Step 1) failed to significantly predict variability in analogue trauma symptoms, accounting for 0.0% of the variance in analogue trauma symptoms after 1 day (T1), $F(1, 78) = 0.11$, $p = .737$. The psychophysiological stress response (Step 2) explained an additional 19.0% of the variance in analogue trauma symptoms (T1), $F(3, 76) = 6.02$, $p = .001$. The addition of cognitive processing (Step 3) to the model significantly explained an additional 6.2% of the variance (T1), $F(4, 75) = 6.37$, $p < .001$. The subsequent addition of cognitive regulation and appraisal to the model (Step 4) accounted for an additional 8.2% of the variance (T1), $F(6, 73) = 6.14$, $p < .001$. Finally, the addition of flexible emotion regulation to the model (Step 5) explained an additional 10.1% of the variance in analogue trauma symptoms, $F(7, 72) = 7.95$, $p < .001$. After entering cognitive regulation and appraisal to the model, subjective stress response was no longer significant. After entering flexibility of emotion regulation to the model, self-blame was no longer a significant predictor of analogue trauma symptoms (T1). In the full model, rumination (β = .250) and flexible emotion regulation (β = − .331) were the strongest predictors of analogue trauma symptoms (T1). Together, the independent variables accounted for 43.6% of the variance in analogue trauma symptoms (T1) ($f^2 = 0.79$). Results regarding analogue trauma symptoms after one day are displayed in Table 4.

Analogue Trauma Symptoms After 1 Week (IES-R)

The control variable depression (Step 1) again accounted for none of the variance in analogue trauma symptoms after 1 week (T2), $F(1, 78) = 0.01$, $p = .941$. The addition of psychophysiological stress response to the model (Step 2) explained 3.2% of the variance in analogue trauma symptoms (T2), but this was not significant, $F(3, 76) = 0.84$, $p = .478$. After entering cognitive processing to the model (Step 3) an additional 9.6% of the variance in analogue trauma symptoms (T2) was explained, which was a significant increase, $F(4, 75) = 2.76$, $p = .034$. The addition of cognitive regulation and appraisal (Step 4) explained an additional 10.2% of variance, $F(6, 73) = 3.65$, $p = .003$. Finally, the addition of flexible emotion regulation (Step 5) explained an additional 1.9% of the variance in analogue trauma symptoms (T2), but this final change in R^2 was not significant. The overall model was significant, $F(7, 72) = 3.42$, p = .003. In the final model, self-blame (β = .346) and peri-traumatic cognitive processing (β = .285) were the most important unique predictors of analogue trauma symptoms (T2). Together, the independent variables accounted for 25.0% of the variance in analogue trauma symptoms (T2) ($f^2 = 0.33$). Results regarding analogue trauma symptoms after one week are shown in Table 4.

Discussion

Previous research has identified peri- and post-traumatic factors (e.g. psychophysiological response, rumination) as most important for the differential development of stress-associated psychopathology or PTSD (Brewin et al. 2000; Ozer et al. 2003; Regambal and Alden 2009; Ripley et al. 2017). However, more comprehensive real-time data about the relationship between emotional subjective and physiological as well as cognitive variables, which are critical for the development of analogue trauma symptoms, are scarce. In this study, we aimed to investigate a range of these peri- and post-traumatic factors in real-time in a laboratory controlled setting using an innovative VR analogue trauma paradigm for experimental stress induction.

Table 3 Descriptive statistics and associations of key study variables

	M (*SD*)	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
1. STAI-S Anxiety	53.80 (9.24)	.28*	.36**	.31**	.32**	.49**	.16	− .01	.24*	.27*	.36**	.39**	− .07	.19	.24*	.17	.06
2. Guilt	1.86 (1.76)	–	.70**	.25*	.31**	.55**	− .08	.07	.26*	.06	.41**	.09	− .08	.23*	.26*	.18	.07
3. Shame	1.59 (1.58)		–	.25*	.33**	.49**	− .14	− .06	.19	.10	.58**	.13	− .20	.31**	.29*	.38*	.01
4. Anger	1.83 (1.77)			–	.28*	.43*	− .01	− .03	.25*	.22*	.23*	.12	− .01	.22*	.30**	.31**	− .01
5. Sadness	1.86 (1.40)				–	.30**	.00	.01	.15	.35**	.36**	.15	.05	.06	.27*	.25*	.09
6. Helplessness	5.72 (2.18)					–	.00	− .09	.38**	.07	.45**	.20	− .10	.28*	.20	.19	.03
7. HR	83.40 (7.26)						–	− .07	.16	− .05	− .06	.15	− .04	− .18	− .14	− .04	.02
8. SCL	1.90 (0.17)							–	− .12	.05	− .12	− .10	− .05	− .16	.07	.05	.22
9. CPQ data-driven	1.66 (0.74)								–	.29**	.35**	.23*	− .08	.33**	.33**	.10	.15
10. CPQ lack of self-reference	1.02 (0.72)									–	.22	.04	− .05	.12	.30**	.13	.36**
11. CERQ self-blame	3.32 (1.38)										–	.12	− .14	.26*	.44**	.34**	.31**
12. CERQ rumination	9.57 (2.68)											–	− .02	.43**	.33**	.25*	− .09
13. PACT	0.31 (0.12)												–	− .47**	− .25*	− .18	− .16
14. IMQ frequency	5.72 (2.87)													–	.70**	.43**	.05
15. IMQ worry % (*N*)	35.00 (26.39)														–	.50**	.19
16. IMQ mental occ. % (*N*)	13.24 (9.79)															–	.32**
17. IES-R total	9.52 (5.63)																–

STAI-S State-Trait Anxiety Inventory-State Version, *HR* Heart Rate, *SCL* Skin Conductance Level, *CPQ* Cognitive Processing Questionnaire, *CERQ* Cognitive Emotion Regulation Questionnaire, *PACT* Perceived Ability to Cope with Trauma Scale, *IMQ* Intrusive Memory Questionnaire (after 1 day), *IES-R* Impact of Event Scale-Revised (after 1 week)

$^{*}p < .05$; $^{**}p < .01$

Table 4 Hierarchical multiple regression analysis predicting analogue trauma symptoms

Predictor	Analogue trauma symptoms			
	T1		T2	
	ΔR^2	β	ΔR^2	β
Step 1: Control variables	.00		.00	
BDI-S		.04		.01
Step 2: Stress response	.19***		.03	
SERS		.44***		.08
PERS		− .09		.16
Step 3: Cognitive processing	.06*		.10**	
CPQ		.27*		.34**
Step 4: Cognitive reg./appraisals	.08*		.10**	
CERQ self-blame		.21		.37**
CERQ rumination		.25*		− .13
Step 5: Flexible emotion regulation	.10***		.02	
PACT		− .33***		− .14
Total R^2	.44***		.25**	
N	80		80	

T1 after 1 day (IMQ), *T2* after 1 week (IES-R), *BDI-S* Beck Depression Inventory-Simplified version, *SERS* Subjective Emotional Response Score, *PERS* Physiological Emotional Response Score, *CPQ* Cognitive Processing Questionnaire, *CERQ* Cognitive Emotion Regulation Questionnaire, *PACT* Perceived Ability to Cope with Trauma Scale

*$p < .05$; **$p < .01$; ***$p < .001$

As expected, the VR analogue trauma induced a complex psychophysiological stress response with a similar range of negative emotions somewhat comparable with emotions triggered by real traumatic experiences, although the intensity of psychophysiological stress response during real trauma has been found to be much higher (Kinateder et al. 2014; Rovira et al. 2009). Thus, our results have added value in capturing the peri-traumatic response in the laboratory and further validate the VR analogue trauma paradigm in modelling trauma responses.

As expected, we found higher levels of peri-traumatic dysfunctional cognitive processing and cognitive regulation and appraisal to uniquely predict more frequent analogue trauma symptoms beyond the peri-traumatic psychophysiological stress response after 1 day and after 1 week. Furthermore, as expected, flexible emotion regulation uniquely predicted analogue trauma symptoms after 1 day, but contrary to our expectations not after 1 week. These findings might highlight in particular the importance of cognitive factors in increasing the risk of developing stress-associated psychopathology.

As a recent advancement in prospective analogue design, we used a VR analogue trauma paradigm for experimental stress induction in a controlled laboratory setting, which overcomes the problem of memory biases in retrospective assessments. In contrast to other well-established paradigms, VR allows for first-person experiences and person–environment interactions, while eliciting higher emotional stress responses than aversive pictures (Courtney et al. 2010) and script-driven imagery (Schweizer et al. 2018) as well as similar stress responses and intrusive memories as trauma films (Becker-Asano et al. 2011; Cuperus et al. 2017; Dibbets and Schulte-Ostermann 2015). Participants in our study reported high levels of presence and involvement. In this regard, smoke exposure as part of the multisensory simulation seemed to be particularly valuable. Symptoms of cyber sickness were rarely present.

Peri-traumatic Psychophysiological Emotional Reactivity

In line with our hypothesis, we found higher psychophysiological reactivity in the analogue trauma compared to the neutral condition on all examined parameters, as has been found in prior studies (Bryant et al. 2008; Pineles et al. 2013; Shalev et al. 1998). In particular, we found large effect sizes of stress reactivity for anxiety, helplessness, guilt, HR, subjective stress and arousal with high absolute levels of anxiety and helplessness during the VR analogue trauma. Previous research revealed that stress and guilt are further associated with less perceived ability to act (Held et al. 2017), which may be especially critical in an emergency situation. Likewise, guilt seems to be associated with the experience of low control and high self-responsibility (Lazarus 1993).

Thus, our results suggest that besides anxiety and peripheral-physiological parameters, a range of other negative emotions also seems to elicit and be distinctive of the peri-traumatic stress response. Likewise, the importance of peri-traumatic emotions for the development of subsequent psychopathology has been shown in previous studies, e.g. regarding guilt, shame, sadness and anger (Beck et al. 2011; Resick and Miller 2009; Rizvi et al. 2008) and supported by clinical evidence in individuals with PTSD (Ozer et al. 2003). This also seems to be important in terms of the efficacy of PTSD treatments, which were developed primarily focusing on anxiety, even though this is not the predominant emotion in most individuals with PTSD (Power and Fyvie 2013). The necessity of exploring a broader range of peri-traumatic emotional responses has been reflected in adapting the criterion of peri-traumatic "fear, helpless, and/or horror" to a broader range of trauma-related emotions such as fear, guilt shame and anger in criterion D of the DSM-5 (American Psychiatric Association 2013).

Gaining more insight into the complex individual emotional responses to stressful events by experimentally modelling trauma exposure and responses may contribute to the identification of critical emotional profiles in coping with stress. This knowledge could be used to detect and support individuals at risk and further enhance the efficacy of existing treatments by including consideration of the predominant emotions apart from anxiety, especially for individuals who have not yet benefited from treatment (e.g. Power and Fyvie 2013).

Post-traumatic Analogue Trauma Symptoms

Higher levels of dysfunctional cognitive processing as well as maladaptive cognitive regulation and appraisal predicted more frequent analogue trauma symptoms beyond the peri-traumatic psychophysiological stress response after 1 day and after 1 week, while flexible emotion regulation predicted analogue trauma symptoms after 1 day but not after 1 week. The final regression models explained 43.6% of the variance in analogue trauma symptoms after 1 day and 25.0% after 1 week.

Depression, which has been identified as associated with trauma symptoms in previous meta analyses of analogue trauma studies as well as clinical studies (Clark et al. 2015; Ozer et al. 2003), was not predictive of analogue trauma symptoms either after 1 day or after 1 week in this study. This is likely explained by the low levels of depressive symptoms in our sample.

In accordance with previous research (Ozer et al. 2003), the subjective stress response was the strongest predictor of analogue trauma symptoms after 1 day ($\beta = .44$), while the psychophysiological stress response was not a significant predictor of analogue trauma symptoms after 1 week. After entering rumination into the model, subjective stress response failed to predict analogue trauma symptoms after 1 day, which might indicate that rumination mediates the relationship between peri-traumatic subjective stress response and subsequent analogue trauma symptoms (Regambal and Alden 2009). This would be in line with a meta-analysis showing that peri-traumatic stress responses seem to be less important over time presumably because of the increasing importance of other factors (Thomas et al. 2012), and seem to be particularly relevant in predicting temporary malfunction (Gandubert et al. 2016). As predictor for analogue trauma symptoms, the induced absolute levels of physiological stress may have been too low or/and HR as a physiological indicator modulated by both sympathetic activity (indicating emotional arousal by increased HR) and parasympathetic activity (indicating information and attention processing by decreased HR) might have been be too ambiguous to capture emotional arousal (Boucsein 2012; Bradley and Lang 2000).

As expected, peri-traumatic cognitive processing predicted unique variance in analogue trauma symptoms after 1 day and especially after 1 week ($\beta = 34$). This might be the result of peri-traumatic impaired memory encoding with primarily data driven versus conceptual processing in the context of high anxiety levels (Laposa and Rector 2012; Logan and O'Kearney 2012) and also impaired integration into autobiographical memory in the context of other self-related experiences (Ehlers and Clark 2000). Previous research has shown that in particular a lack of self-referential processing seems to be critical for the development of PTSD symptoms (Laposa and Rector 2012) and might be associated with rumination (Mennin and Fresco 2013).

As predicted, cognitive regulation and appraisal further explained unique variance above and beyond the other variables, indicating that maladaptive cognitions are also important in predicting analogue trauma symptoms by rumination after 1 day and especially by self-blame after 1 week ($\beta = .37$). This is consistent with previous studies, which have found associations between PTSD symptoms and self-blame (with a similar effect of $\beta = .31$) (Hansen et al. 2014) as well as rumination (Michael et al. 2007). Furthermore, our results are in accordance with the cognitive model of Ehlers and Clark (2000), which considers maladaptive cognitions and appraisals to be critical for a sense of ongoing threat and avoidance of trauma-related stimuli thereby inhibiting trauma memory integration/elaboration and resulting in persistent PTSD symptoms (Dunmore et al. 2001; Halligan et al. 2003; Nolen-Hoeksema et al. 2008). With respect to the content of the VR analogue trauma the existence of rumination and self-blame is likely related to the presence of the injured person within the VR analogue trauma. Similarly to real emergency situations it was not possible to help the person, which should induce helplessness as a common feeling in traumatic situations (Ozer et al. 2003). Rumination has been initially found to have a focus on the past, e.g. trying to make sense of what happened (McLaughlin et al. 2007; Nolen-Hoeksema et al. 2008). Self-blame with inherently high self-relevance as a strong, later-occurring important predictor of trauma analogue symptoms might be particularly critical for PTSD development, since trauma symptoms and negative self-related cognitions could interact dysfunctionally, which could further maintain psychopathology (Shahar et al. 2013). Thus, the relationship between self-related negative cognitions and traumatic symptoms seems to increase over time, which is consistent with other studies (e.g. O'Donnell et al. 2007).

As expected, we found that flexible emotion regulation was a strong predictor of analogue trauma symptoms after 1 day ($\beta = -.33$), but in contrary to our expectations not after 1 week. This is consistent with current research findings that the flexible application of different strategies in stressful situations is associated with fewer traumatic symptoms and might be the most adaptive way to cope with traumatic stress (Bonanno et al. 2011a; Pinciotti et al. 2017; Rodin et al. 2017). The result that flexibility is only an important predictor 1 day after analogue trauma may be explained by the analogue nature of the event with moderate intensity.

Therefore, prompt regulation with a focus on the experienced event as well as on the future life seems sufficient (Galatzer-Levy et al. 2012).

Our findings highlight the influence of regulatory mechanisms such as cognitive regulation by rumination and flexible emotion regulation in response to a strong subjective stress response and dysfunctional cognitive processing on analogue trauma symptoms after 1 day. Cognitive processing and especially maladaptive appraisal by self-blame were important in predicting analogue trauma symptoms after 1 week. Hence, the results are consistent with cognitive models of PTSD (Ehlers and Clark 2000), showing that in particular cognitive peri- and post-traumatic factors are crucial in conferring risk for stress-associated psychopathology, and moreover that their importance seemed to increase over time. This further implies that the general time course of symptom development seems to be adequately modelled by the VR analogue trauma paradigm, which is in line with previous studies (Hansen et al. 2014; Mc Farlane 2000; Solberg et al. 2016).

Limitations

A number of limitations of the study should be noted. Notwithstanding the numerous advantages of the VR analogue design, the analogue setting is not intended to replicate trauma responses in intensity, thereby the generalisability of our findings to the real world is limited, although the reaction patterns seem similar (Kinateder et al. 2014; Rovira et al. 2009; Schweizer et al. 2017, 2018). In addition, very low levels of depression as well as the a priori screening of the absence of prior traumatic events in our sample limit the generalisability to clinical and at risk populations. In addition, the sample was unbalanced in terms of gender, which precluded certain analyses. Although we tested a range of empirically important predictors, we did not exhaustively investigate all potentially relevant predictors and their complex interactions, e.g. by structural equation models (SEM) (Regambal and Alden 2009; Schweizer et al. 2017). To investigate the data driven and self-referential subscales of the CPQ and all emotional subcomponents as separate predictors instead of using composite scores would be of interest for future studies. Concerning the outcome measures, analogue trauma symptoms were investigated with different questionnaires after 1 day (IMQ) and 1 week (IES-R), thus no direct comparison is possible. Furthermore, this might also explain, why some predictors significantly predicted analogue trauma symptoms for one but not the other time point. Intrusive memories were assessed for all modalities and at two time points and not continuously for 1 week. The results should be replicated in longitudinal studies with the same measurement instruments at all time points.

Implications

Based on our results we suggest that future studies should investigate the wider range of individual emotional responses to stressful events by experimentally modelling trauma exposure and responses, including the assessment of possible interactions. The identification of critical emotional profiles in coping with stress could better enable individuals at risk to be detected and treatments could be made more efficient, especially for non-responders (e.g. Power and Fyvie 2013). Given the importance of maladaptive cognitive regulation as a modifiable risk factor in the aetiology of analogue trauma psychopathology, we propose focusing on this. For both rumination and self-blame, acceptance-based approaches could change negative appraisals and reduce avoidance (Shipherd et al. 2016). In addition, approaches such as cognitive bias modification to change negative cognitions by reappraisal training in the context of stress, resulting in fewer analogue trauma symptoms are promising (Woud et al. 2012) even if applied before stress exposure (Woud et al. 2013). In addition, PTSD symptom reduction using cognitive processing therapy seems to be based on changes in self-related maladaptive post-traumatic cognitions (Schumm et al. 2015). Here, negative beliefs about the self, often related to rumination, seem to increase depressive symptoms which then might increase self-blame cognitions, and in turn seem to heighten again depressive symptoms and thereby PTSD symptoms. However, changing cognitive regulation style before the experience of a traumatic event to prevent symptom development in the first place should be preferred (García-Campayo et al. 2015). Furthermore, training flexibility in the use of emotion regulation strategies depending on the context seems to be particularly adaptive in coping with stress (Cheng et al. 2012). The multisensory VR analogue trauma offers an experimental psychopathology model to investigate trauma exposure and responses in real-time and under controlled conditions (Schweizer et al. 2017, 2018). Future studies of stress-associated psychopathology in VR (e.g. Gaggioli et al. 2014) could target peri- and post-traumatic appraisals and emotion regulation modifications in real-time.

Conclusion

In conclusion, our study validated the applied prospective VR analogue trauma paradigm as an experimental psychopathological model to assess stress exposure and responses in real time, in order to identify essential regulatory mechanisms acting during and directly after an analogue trauma and their effects on subsequent analogue trauma symptoms. Furthermore, the findings suggest that over and above the importance of peri-traumatic diverse negative emotions and maladaptive cognitive processing, regulatory mechanisms such as cognitive regulation and appraisals as well as flexible regulation seem crucial for the development of analogue trauma symptoms following exposure to a VR analogue trauma stress induction. Our results indicate in particular the potential effects of emotion regulation flexibility and rumination on early analogue trauma symptoms after 1 day, and highlight the importance of cognitive processing and self-blame on later analogue trauma symptoms after 1 week. While flexible emotion regulation seems to be particularly important directly after analogue trauma exposure, the impact of cognitive factors in predicting analogue trauma symptoms seems to increase over time. Our findings provide initial evidence that flexible emotion regulation might be protective directly after trauma exposure and highlight the general and increasing importance over time of peri- and posttraumatic cognitive factors in the development and maintenance of stress-associated psychopathology, thereby supporting cognitive models of PTSD.

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Compliance with Ethical Standards

Conflict of Interest T. Schweizer, Fritz Renner, Dali Sun, Christian Becker-Asano and Brunna Tuschen-Caffier declare that they have no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

Animal Rights No animal studies were carried out by the authors for this article.

References

Aakvaag, H. F., Thoresen, S., Wentzel-Larsen, T., Dyb, G., Røysamb, E., & Olff, M. (2016). Broken and guilty since it happened: A population study of trauma-related shame and guilt after violence and sexual abuse. *Journal of Affective Disorders, 204*, 16–23. https://doi.org/10.1016/J.JAD.2016.06.004.

Aakvaag, H. F., Thoresen, S., Wentzel-Larsen, T., Røysamb, E., & Dyb, G. (2014). Shame and guilt in the aftermath of terror: The Utøya Island Study. *Journal of Traumatic Stress, 27*(5), 618–621. https://doi.org/10.1002/jts.21957.

Aldao, A., Sheppes, G., & Gross, J. J. (2015). Emotion regulation flexibility. *Cognitive Therapy and Research, 39*(3), 263–278. https://doi.org/10.1007/s10608-014-9662-4.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Arlington: American Psychiatric Publishing. https://doi.org/10.1176/appi.books.9780890425596.744053.

Beck, A. T., Epstein, N., Brown, G., & Steer, R. A. (1988). An inventory for measuring clinical anxiety: Psychometric properties. *Journal of Consulting and Clinical Psychology, 56*(6), 893–897. https://doi.org/10.1037/0022-006X.56.6.893.

Beck, A. T., Steer, R. A., & Brown, G. K. (1996). *Manual for the Beck depression inventory-II*. San Antonio: Psychological Corporation.

Beck, J. G., McNiff, J., Clapp, J. D., Olsen, S. A., Avery, M. L., & Hagewood, J. H. (2011). Exploring negative emotion in women experiencing intimate partner violence: Shame, guilt, and PTSD. *Behavior Therapy, 42*(4), 740–750. https://doi.org/10.1016/j.beth.2011.04.001.

Becker-Asano, C., Sun, D., Kleim, B., Scheel, C. N., Tuschen-Caffier, B., & Nebel, B. (2011). Outline of an empirical study on the effects of emotions on strategic behavior in virtual emergencies. In S. D'Mello, A. Graessner, B. Schuller & J.-C. Martin (Eds.), *Affective computing and intelligent interaction* (pp. 508–517). Berlin: Springer. https://doi.org/10.1007/978-3-642-24571-8_64.

Benight, C. C., & Bandura, A. (2004). Social cognitive theory of posttraumatic recovery: The role of perceived self-efficacy. *Behaviour Research and Therapy, 42*, 1129–1148. https://doi.org/10.1016/j.brat.2003.08.008.

Berntsen, D., & Rubin, D. C. (2006). The centrality of event scale: A measure of integrating a trauma into one's identity and its relation to post-traumatic stress disorder symptoms. *Behaviour Research and Therapy, 44*(2), 219–231. https://doi.org/10.1016/J.BRAT.2005.01.009.

Berntson, G. G., Cacioppo, J. T., Binkley, P. F., Uchino, B. N., Quigley, K. S., & Fieldstone, A. (1994). Autonomic cardiac control. III. Psychological stress and cardiac response in autonomic space as revealed by pharmacological blockades. *Psychophysiology, 31*(6), 599–608.

Blechert, J., Peyk, P., Liedlgruber, M., & Wilhelm, F. H. (2016). ANSLAB: Integrated multichannel peripheral biosignal processing in psychophysiological science. *Behavior Research Methods, 48*(4), 1528–1545. https://doi.org/10.3758/s13428-015-0665-1.

Blix, I., Solberg, Ø, & Heir, T. (2014). Centrality of event and symptoms of posttraumatic stress disorder after the 2011 Oslo bombing attack. *Applied Cognitive Psychology, 28*(2), 249–253. https://doi.org/10.1002/acp.2988.

Boden, J. M., Fergusson, D. M., Horwood, L. J., & Mulder, R. T. (2015). The role of peri-traumatic stress and disruption distress in predicting post-traumatic stress disorder symptoms following exposure to a natural disaster. *BJPsych Open, 1*(01), 81–86. https://doi.org/10.1192/bjpo.bp.115.001180.

Bonanno, G. A., Papa, A., Lalande, K., Westphal, M., & Coifman, K. (2004). The importance of being flexible: The ability to both enhance and suppress emotional expression predicts long-term adjustment. *Psychological Science, 15*(7), 482–487. https://doi.org/10.1111/j.0956-7976.2004.00705.x.

Bonanno, G. A., Pat-Horenczyk, R., & Noll, J. (2011a). Coping flexibility and trauma: The Perceived Ability to Cope With Trauma (PACT) scale. *Psychological Trauma: Theory, Research, Practice, and Policy, 3*(2), 117–129. https://doi.org/10.1037/a0020921.

Bonanno, G. A., Westphal, M., & Mancini, A. D. (2011b). Resilience to loss and potential trauma. *Annual Review of Clinical Psychology, 7*(1), 511–535. https://doi.org/10.1146/annurev-clinpsy-032210-104526.

Bordnick, P. S., Graap, K. M., Copp, H. L., Brooks, J., & Ferrer, M. (2005). Virtual reality cue reactivity assessment in cigarette smokers. *CyberPsychology & Behavior, 8*(5), 487–492. https://doi.org/10.1089/cpb.2005.8.487.

Boucsein, W. (2012). *Electrodermal activity* (2nd ed.). New York: Springer.

Bovin, M. J., & Marx, B. P. (2011). The importance of the peritraumatic experience in defining traumatic stress. *Psychological Bulletin, 137*(1), 47–67. https://doi.org/10.1037/a0021353.

Bradley, M. M., & Lang, P. J. (2000). Measuring emotion: Behavior, feeling, and physiology. In R. D. Lane & L. Nadel (Eds.), *Cognitive neuroscience of emotion* (pp. 242–276). New York: Oxford University Press.

Brewin, C. R., Andrews, B., & Valentine, J. D. (2000). Meta-Analysis of risk factors for post traumatic stress disorder in trauma-exposed adults. *Journal of Consulting and Clinical Psychology, 68*(5), 748–766. https://doi.org/10.1037//0022-006X.68.5.748.

Brown, A. D., Antonius, D., Kramer, M., Root, J. C., & Hirst, W. (2010). Trauma centrality and PTSD in veterans returning from Iraq and Afghanistan. *Journal of Traumatic Stress, 23*(4), 496–499. https://doi.org/10.1002/jts.20547.

Brunet, A., Weiss, D. S., Metzler, T. J., Best, S. R., Neylan, T. C., Rogers, C., et al. (2001). The peritraumatic distress inventory: A proposed measure of PTSD criterion A2. *The American Journal of Psychiatry, 158*(9), 1480–1485. https://doi.org/10.1176/appi.ajp.158.9.1480.

Bryant, R. A., Creamer, M., O'Donnell, M., Silove, D., & McFarlane, A. C. (2008). A multisite study of initial respiration rate and heart rate as predictors of posttraumatic stress disorder. *The Journal of Clinical Psychiatry, 69*(11), 1694–1701. https://doi.org/10.4088/JCP.v69n1104.

Bryant, R. A., Harvey, A. G., Guthrie, R. M., & Moulds, M. L. (2000). A prospective study of psychophysiological arousal, acute stress disorder, and posttraumatic stress disorder. *Journal of Abnormal Psychology, 109*(2), 341–344. https://doi.org/10.1037/0021-843X.109.2.341.

Cacioppo, J. T., Uchino, B. N., & Berntson, G. G. (1994). Individual differences in the autonomic origins of heart rate reactivity: The psychometrics of respiratory sinus arrhythmia and preejection period. *Psychophysiology, 31*(4), 412–419. https://doi.org/10.1111/j.1469-8986.1994.tb02449.x.

Cheng, C., Kogan, A., & Chio, J. H. M. (2012). The effectiveness of a new, coping flexibility intervention as compared with a cognitive-behavioural intervention in managing work stress. *Work and Stress, 26*(3), 272–288. https://doi.org/10.1080/02678373.2012.710369.

Clark, I. A., Mackay, C. E., & Holmes, E. A. (2015). Low emotional response to traumatic footage is associated with an absence of analogue flashbacks: An individual participant data meta-analysis of 16 trauma film paradigm experiments. *Cognition & Emotion, 29*(4), 702–713. https://doi.org/10.1080/02699931.2014.926861.

Cohen, J. (1988). *Statistical power analysis for the behavioural sciences* (2nd ed.). Hillsdale: Lawrence Earlbaum Associates.

Courtney, C. G., Dawson, M. E., Schell, A. M., Iyer, A., & Parsons, T. D. (2010). Better than the real thing: Eliciting fear with moving and static computer-generated stimuli. *International Journal of Psychophysiology, 78*(2), 107–114. https://doi.org/10.1016/j.ijpsycho.2010.06.028.

Critchley, H. D. (2002). Review: Electrodermal responses: What happens in the brain. *The Neuroscientist, 8*(2), 132–142. https://doi.org/10.1177/107385840200800209.

Cunningham, K. C., Davis, J. L., Wilson, S. M., & Resick, P. A. (2017). A relative weights comparison of trauma-related shame and guilt as predictors of DSM-5 posttraumatic stress disorder symptom severity among US veterans and military members. *British Journal of Clinical Psychology*. https://doi.org/10.1111/bjc.12163.

Cuperus, A. A., Klaassen, F., Hagenaars, M. A., & Engelhard, I. M. (2017). A virtual reality paradigm as an analogue to real-life trauma: Its effectiveness compared with the trauma film paradigm. *European Journal of Psychotraumatology, 8*(Suppl 1), 1338106. https://doi.org/10.1080/20008198.2017.1338106.

Dibbets, P., & Schulte-Ostermann, M. A. (2015). Virtual reality, real emotions: A novel analogue for the assessment of risk factors of post-traumatic stress disorder. *Frontiers in Psychology, 6*, 681. https://doi.org/10.3389/fpsyg.2015.00681.

Dunmore, E., Clark, D. M., & Ehlers, A. (2001). A prospective investigation of the role of cognitive factors in persistent Posttraumatic Stress Disorder (PTSD) after physical or sexual assault. *Behaviour Research and Therapy, 39*(9), 1063–1084. https://doi.org/10.1016/S0005-7967(00)00088-7.

Ehlers, A. (2002). *Processing styles questionnaire*.

Ehlers, A., & Clark, D. M. (2000). A cognitive model of posttraumatic stress disorder. *Behaviour Research and Therapy, 38*(4), 319–345. https://doi.org/10.1016/S0005-7967(99)00123-0.

Ehlers, A., Mayou, R. A., & Bryant, B. (1998). Psychological predictors of chronic posttraumatic stress disorder after motor vehicle accidents. *Journal of Abnormal Psychology, 107*(3), 508–519. https://doi.org/10.1037/0021-843X.107.3.508.

Foa, E. B., Cashman, L., Jaycox, L., & Perry, K. (1997). The validation of a self-report measure of posttraumatic stress disorder: The Posttraumatic Diagnostic Scale. *Psychological Assessment, 9*(4), 445–451. https://doi.org/10.1037/1040-3590.9.4.445.

Franke, G. H. (2000). *Brief Symptom Inventory (BSI)*. Göttingen: Beltz Test GmbH.

Gaggioli, A., Pallavicini, F., Morganti, L., Serino, S., Scaratti, C., Briguglio, M., et al. (2014). Experiential virtual scenarios with real-time monitoring (interreality) for the management of psychological stress: A block randomized controlled trial. *Journal of Medical Internet Research, 16*(7), e167. https://doi.org/10.2196/jmir.3235.

Galatzer-Levy, I. R., Burton, C. L., & Bonanno, G. A. (2012). Coping flexibility, potentially traumatic life events, and resilience: A prospective study of college student adjustment. *Journal of Social and Clinical Psychology, 31*(6), 542–567.

Gandubert, C., Scali, J., Ancelin, M.-L., Carrière, I., Dupuy, A.-M., Bagnolini, G., et al. (2016). Biological and psychological predictors of posttraumatic stress disorder onset and chronicity. A one-year prospective study. *Neurobiology of Stress, 3*, 61–67. https://doi.org/10.1016/j.ynstr.2016.02.002.

García-Campayo, J., del Hoyo, Y. L., Valero, M. S., Yus, M. C. P., Esteban, E. A., Guedea, M. P., et al. (2015). Primary prevention of anxiety disorders in primary care: A systematic review. *Preventive Medicine, 76*, S12–S15. https://doi.org/10.1016/j.ypmed.2014.10.015.

Garnefski, N., & Kraaij, V. (2007). The Cognitive Emotion Regulation Questionnaire. *European Journal of Psychological Assessment, 23*(3), 141–149. https://doi.org/10.1027/1015-5759.23.3.141.

Hair, J. F., Black, W. C., Babin, B. J., & Anders, R. E. (2010). *Multivariate data analysis: A global perspective* (7th ed.). Upper Saddle River: Pearson.

Halligan, S. L., Clark, D. M., & Ehlers, A. (2002). Cognitive processing, memory, and the development of PTSD symptoms: Two experimental analogue studies. *Journal of Behavior Therapy and Experimental Psychiatry, 33*(2), 73–89. https://doi.org/10.1016/S0005-7916(02)00014-9.

Halligan, S. L., Michael, T., Clark, D. M., & Ehlers, A. (2003). Posttraumatic stress disorder following assault: The role of cognitive processing, trauma memory, and appraisals. *Journal of Consulting and Clinical Psychology, 71*(3), 419–431. https://doi.org/10.1037/0022-006X.71.3.419.

Hansen, M., Armour, C., Wittmann, L., Elklit, A., & Shevlin, M. (2014). Is there a common pathway to developing ASD and PTSD symptoms? *Journal of Anxiety Disorders, 28*(8), 865–872. https://doi.org/10.1016/J.JANXDIS.2014.09.019.

Held, P., Owens, G. P., Monroe, J. R., & Chard, K. M. (2017). Increased mindfulness skills as predictors of reduced trauma-related guilt in treatment-seeking Veterans. *Journal of Traumatic Stress, 30*(4), 425–431. https://doi.org/10.1002/jts.22209.

Hinrichs, R., van Rooij, S., Michopoulos, V., Rothbaum, B., & Ressler, K. (2018). Skin conductance response in the emergency department predicts future PTSD symptom severity. *Biological Psychiatry, 83*(9), S143. https://doi.org/10.1016/j.biopsych.2018.02.374.

Hinz, A., Seibt, R., Hueber, B., & Schreinicke, G. (2000). Response specificity in psychophysiology. *Journal of Psychophysiology, 14*(2), 115–122. https://doi.org/10.1027//0269-8803.14.2.115.

Jänig, W., & Häbler, H. J. (2000). Specificity in the organization of the autonomic nervous system: A basis for precise neural regulation of homeostatic and protective body functions. *Progress in Brain Research, 122*, 351–367.

Kinateder, M., Ronchi, E., Nilsson, D., Kobes, M., Müller, M., Pauli, P., et al. (2014). Virtual reality for fire evacuation research. In A. Krasuski & G. Rein (Eds.), *Federated conference on computer science and information systems*. (pp. 313–321). New York: IEEE. https://doi.org/10.15439/2014F94.

Kreibig, S. D. (2010). Autonomic nervous system activity in emotion: A review. *Biological Psychology, 84*(3), 394–421. https://doi.org/10.1016/J.BIOPSYCHO.2010.03.010.

Laposa, J. M., & Alden, L. E. (2008). The effect of pre-existing vulnerability factors on a laboratory analogue trauma experience. *Journal of Behavior Therapy and Experimental Psychiatry, 39*(4), 424–435. https://doi.org/10.1016/j.jbtep.2007.11.002.

Laposa, J. M., & Rector, N. A. (2012). The prediction of intrusions following an analogue traumatic event: Peritraumatic cognitive processes and anxiety-focused rumination versus rumination in response to intrusions. *Journal of Behavior Therapy and Experimental Psychiatry, 43*(3), 877–883. https://doi.org/10.1016/j.jbtep.2011.12.007.

Laux, L., Glanzmann, P., Schaffner, P., & Spielberger, C. (1981). *Das State-Trait-Angstinventar (STAI) [State-Trait-Anxiety Inventory (STAI)]*. Weinheim: Beltz.

Lazarus, R. S. (1993). The emotions: A history of changing outlooks. *Annual Review of Psychology, 44*(1), 1–21. https://doi.org/10.1146/annurev.ps.44.020193.000245.

Lazarus, R. S., & Folkman, S. (1984). *Stress, appraisal and coping*. New York: Springer Publishing Company.

LeBlanc, V. R., Regehr, C., Birze, A., King, K., Scott, A. K., MacDonald, R., et al. (2011). The association between posttraumatic stress, coping, and acute stress responses in paramedics. *Traumatology, 17*(4), 10–16. https://doi.org/10.1177/1534765611429078.

Lee, D. A., Scragg, P., & Turner, S. (2001). The role of shame and guilt in traumatic events: A clinical model of shame-based and guilt-based PTSD. *British Journal of Medical Psychology, 74*(4), 451–466. https://doi.org/10.1348/000711201161109.

Lesage, F.-X., Berjot, S., & Deschamps, F. (2012). Clinical stress assessment using a visual analogue scale. *Occupational Medicine, 62*(8), 600–605. https://doi.org/10.1093/occmed/kqs140.

Leskela, J., Dieperink, M., & Thuras, P. (2002). Shame and posttraumatic stress disorder. *Journal of Traumatic Stress, 15*(3), 223–226. https://doi.org/10.1023/A:1015255311837.

Leung, S.-O. (2011). A comparison of psychometric properties and normality in 4-, 5-, 6-, and 11-point likert scales. *Journal of Social Service Research, 37*(4), 412–421. https://doi.org/10.1080/01488376.2011.580697.

Loch, N., Hiller, W., & Witthöft, M. (2011). Der cognitive emotion regulation questionnaire (CERQ). Erste teststatistische Überprüfung einer deutschen Adaption. *Zeitschrift fur Klinische Psychologie und Psychotherapie, 40*(2), 94–106.

Logan, S., & O'Kearney, R. (2012). Individual differences in emotionality and peri-traumatic processing. *Journal of Behavior Therapy and Experimental Psychiatry, 43*(2), 815–822. https://doi.org/10.1016/J.JBTEP.2011.12.003.

Maercker, A., & Schützwohl, M. (1998). Erfassung von psychischen Belastungssfolgen: Die impact of event Skala—Revidierte Version. *Diagnostica, 44*, 130–141.

Margraf, J., & Ehlers, A. (2007). *Beck Angst-Inventar (BAI)*. Frankfurt am Main: Harcourt Test Services GmbH.

Mathews, A. (1990). Why worry? The cognitive function of anxiety. *Behaviour Research and Therapy, 28*(6), 455–468. https://doi.org/10.1016/0005-7967(90)90132-3.

Matthieu, M., Lewis, S. J., Ivanoff, A., & Conroy, K. (2007). School of social work disaster response following the world trade center disaster: MSW student and field instructor perspectives. *Brief Treatment and Crisis Intervention, 7*(2), 115–126. https://doi.org/10.1093/brief-treatment/mhm003.

Mc Farlane, A. C. (2000). Posttraumatic stress disorder: A model of the longitudinal course and the role of risk factors. *The Journal of Clinical Psychiatry, 61*(5), 15–20.

McLaughlin, K. a., Borkovec, T. D., & Sibrava, N. J. (2007). The effects of worry and rumination on affect states and cognitive activity. *Behavior Therapy, 38*(1), 23–38. https://doi.org/10.1016/j.beth.2006.03.003.

Meiser-Stedman, R., Dalgleish, T., Glucksman, E., Yule, W., & Smith, P. (2009). Maladaptive cognitive appraisals mediate the evolution of posttraumatic stress reactions: A 6-month follow up of child and adolescent assault and motor vehicle accident survivors. *Journal of Abnormal Psychology, 118*, 778.

Mennin, D. S., & Fresco, D. M. (2013). What, me worry and ruminate about DSM-5 and RDoC? The importance of targeting negative self-referential processing. *Clinical Psychology: Science and Practice, 20*(3), 258–267. https://doi.org/10.1111/cpsp.12038.

Michael, T., & Ehlers, A. (2007). Enhanced perceptual priming for neutral stimuli occurring in a traumatic context: Two experimental investigations. *Behaviour Research and Therapy, 45*(2), 341–358. https://doi.org/10.1016/j.brat.2006.03.012.

Michael, T., Halligan, S. L., Clark, D. M., & Ehlers, A. (2007). Rumination in posttraumatic stress disorder. *Depression and Anxiety, 24*(5), 307–317. https://doi.org/10.1002/da.20228.

Munyan, B. G., Neer, S. M., Beidel, D. C., Jentsch, F., Sayer, N., & Nugent, S. (2016). Olfactory stimuli increase presence in virtual environments. *PLoS ONE, 11*(6), e0157568. https://doi.org/10.1371/journal.pone.0157568.

Nolen-Hoeksema, S., Wisco, B. E., & Lyubomirsky, S. (2008). Rethinking rumination. *Perspectives on Psychological Science, 3*(5), 400–424. https://doi.org/10.1111/j.1745-6924.2008.00088.x.

O'Donnell, M. L., Elliott, P., Lau, W., & Creamer, M. (2007). PTSD symptom trajectories: From early to chronic response. *Behaviour Research and Therapy, 45*(3), 601–606. https://doi.org/10.1016/j.brat.2006.03.015.

Ozer, E. J., Best, S. R., Lipsey, T. L., & Weiss, D. S. (2003). Predictors of posttraumatic stress disorder and symptoms in adults: A meta-analysis. *Psychological Bulletin, 129*(1), 52–73. https://doi.org/10.1037/1942-9681.S.1.3.

Pinciotti, C. M., Seligowski, A. V., & Orcutt, H. K. (2017). Psychometric properties of the PACT scale and relations with symptoms of PTSD. *Psychological Trauma: Theory, Research, Practice, and Policy, 9*(3), 362–369. https://doi.org/10.1037/tra0000206.

Pineles, S. L., Suvak, M. K., Liverant, G. I., Gregor, K., Wisco, B. E., Pitman, R. K., et al. (2013). Psychophysiologic reactivity, subjective distress, and their associations with PTSD diagnosis. *Journal of Abnormal Psychology, 122*(3), 635–644. https://doi.org/10.1037/a0033942.

Power, M. J., & Fyvie, C. (2013). The role of emotion in PTSD: Two preliminary studies. *Behavioural and Cognitive Psychotherapy, 41*(02), 162–172. https://doi.org/10.1017/S1352465812000148.

Regambal, M. J., & Alden, L. E. (2009). Pathways to intrusive memories in a trauma analogue paradigm: A structural equation model. *Depression and Anxiety, 26*(2), 155–166. https://doi.org/10.1002/da.20483.

Resick, P. A., & Miller, M. W. (2009). Posttraumatic stress disorder: Anxiety or traumatic stress disorder? *Journal of Traumatic Stress, 22*(5), 384–390. https://doi.org/10.1002/jts.20437.

Ripley, A. J., Clapp, J. D., & Beck, J. G. (2017). A prospective examination of risk factors in the development of intrusions following a trauma analog. *Behaviour Research and Therapy, 94*, 71–80. https://doi.org/10.1016/J.BRAT.2017.05.001.

Rizvi, S., Kaysen, D., Gutner, C., Griffin, M. G., & Resick, P. a. (2008). The role of peritraumatic responses in posttraumatic stress female crime victims. *Journal of Interpersonal Violence, 23*(6), 853–868. https://doi.org/10.1177/0886260508314851.

Rodin, R., Bonanno, G. A., Knuckey, S., Satterthwaite, M. L., Hart, R., Joscelyne, A., et al. (2017). Coping flexibility predicts posttraumatic stress disorder and depression in human rights advocates. *International Journal of Mental Health, 46*(4), 327–338. https://doi.org/10.1080/00207411.2017.1345047.

Rovira, A., Swapp, D., Spanlang, B., & Slater, M. (2009). The use of virtual reality in the study of people's responses to violent incidents. *Frontiers in Behavioral Neuroscience, 3*(December), 1–10. https://doi.org/10.3389/neuro.08.059.2009.

Rubin, D. C., Berntsen, D., & Bohni, M. K. (2008). A memory-based model of posttraumatic stress disorder: Evaluating basic assumptions underlying the PTSD diagnosis. *Psychological Review, 115*(4), 985–1011. https://doi.org/10.1037/a0013397.

Schmitt, M., Altstötter-Gleich, C., Hinz, A., Maes, J., & Brähler, E. (2006). Normwerte für das Vereinfachte Beck-Depressions-Inventar (BDI-V) in der Allgemeinbevölkerung. *Diagnostica, 52*(2), 51–59. https://doi.org/10.1026/0012-1924.52.2.51.

Schmitt, M., Beckmann, M., Dusi, D., Maes, J., Schiller, A., & Schonauer, K. (2003). Messgüte des vereinfachten Beck-Depressions-Inventars (BDI-V). *Diagnostica, 49*(4), 147–156. https://doi.org/10.1026//0012-1924.49.4.147.

Schmitt, M., & Maes, J. (2000). Vorschlag zur Vereinfachung des Beck-Depressions-Inventars (BDI). *Diagnostica, 46*(1), 38–46. https://doi.org/10.1026//0012-1924.46.1.38.

Schubert, T. (2003). The sense of presence in virtual environments: A three-component scale measuring spatial presence, involvement, and realness. *Zeitschrift Für Medienpsychologie, 15*(2), 69–71. https://doi.org/10.1026//1617-6383.15.2.69.

Schubert, T., Friedmann, F., & Regenbrecht, H. (2001). The experience of presence: Factor analytic insights. *Presence, 10*(3), 266–281.

Schumm, J. A., Dickstein, B. D., Walter, K. H., Owens, G. P., & Chard, K. M. (2015). Changes in posttraumatic cognitions predict changes in posttraumatic stress disorder symptoms during cognitive processing therapy. *Journal of Consulting and Clinical Psychology, 83*(6), 1161–1166. https://doi.org/10.1037/ccp0000040.

Schweizer, T., Renner, F., Sun, D., Kleim, B., Holmes, E., & Tuschen-Caffier, B. (2018). Psychophysiological reactivity, coping behaviour and intrusive memories upon multisensory Virtual Reality and Script-driven imagery analogue trauma: A randomised controlled crossover study. *Journal of Anxiety Disorders*. https://doi.org/10.1016/j.janxdis.2018.08.005 (**in press**).

Schweizer, T., Schmitz, J., Plempe, L., Sun, D., Becker-Asano, C., Leonhart, R., et al. (2017). The impact of pre-existing anxiety on affective and cognitive processing of a Virtual Reality analogue trauma. *PLoS ONE, 12*(12), e0190360. https://doi.org/10.1371/journal.pone.0190360.

Seligowski, A. V., Lee, D. J., Bardeen, J. R., & Orcutt, H. K. (2015). Emotion regulation and posttraumatic stress symptoms: A meta-analysis. *Cognitive Behaviour Therapy, 44*(2), 87–102.

Shahar, G., Noyman, G., Schnidel-Allon, I., & Gilboa-Schechtman, E. (2013). Do PTSD symptoms and trauma-related cognitions about the self constitute a vicious cycle? Evidence for both cognitive vulnerability and scarring models. *Psychiatry Research, 205*(1–2), 79–84. https://doi.org/10.1016/J.PSYCHRES.2012.07.053.

Shalev, A. Y., Sahar, T., Freedman, S., Peri, T., Glick, N., Brandes, D., et al. (1998). A prospective study of heart rate response following trauma and the subsequent development of posttraumatic stress disorder. *Archives of General Psychiatry, 55*(6), 553–559. https://doi.org/10.1001/archpsyc.55.6.553.

Shipherd, J. C., Salters-Pedneault, K., Fordiani, J., & Fordiani, J. (2016). Evaluating postdeployment training for coping with intrusive cognition: A comparison of training approaches. *Journal of Consulting and Clinical Psychology, 84*(11), 960–971. https://doi.org/10.1037/ccp0000136.

Soeter, M., & Kindt, M. (2013). High trait anxiety: A challenge for disrupting fear memory reconsolidation. *PLoS ONE, 8*(11), e75239. https://doi.org/10.1371/journal.pone.0075239.

Solberg, Ø, Birkeland, M. S., Blix, I., Hansen, M. B., & Heir, T. (2016). Towards an exposure-dependent model of post-traumatic stress: Longitudinal course of post-traumatic stress symptomatology and functional impairment after the 2011 Oslo bombing. *Psychological Medicine, 46*(15), 3241–3254. https://doi.org/10.1017/S0033291716001860.

Soper, D. S. (2018). A-priori sample size calculator for hierarchical multiple regression [software]. Retrieved February 12, 2018, from http://www.danielsoper.com/statcalc.

Spielberger, C. D., Gorsuch, R. L., Lushene, P. R., Vagg, P. R., & Jacobs, A. G. (1983). *Manual for the state-trait anxiety inventory (STAI)*. Palo Alto: Consulting Psychologists Press.

Thomas, É, Saumier, D., & Brunet, A. (2012). Peritraumatic distress and the course of posttraumatic stress disorder symptoms: A meta-analysis. *The Canadian Journal of Psychiatry, 57*(2), 122–129. https://doi.org/10.1177/070674371205700209.

Weidmann, A., Conradi, A., Groger, K., Fehm, L., & Fydrich, T. (2009). Using stressful films to analyze risk factors for PTSD in analogue experimental studies—Which film works best? *Anxiety, Stress, and Coping, 22*(5), 549–569. https://doi.org/10.1080/10615800802541986.

Weiss, D. S., & Marmar, C. R. (1997). The Impact of Event Scale-Revised (IES-R). In J. P. Wilson & T. M. Keane (Eds.), *Assessing psychological trauma and PTSD* (pp. 399–411). New York: Guilford Press.

Wilhelm, F. H., & Peyk, P. (2005). *ANSLAB: Autonomic Nervous System Laboratory 4.0 [Computer Software]*. Basel: Wilhelm & Peyk.

Woud, M. L., Holmes, E. A., Postma, P., Dalgleish, T., & Mackintosh, B. (2012). Ameliorating intrusive memories of distressing experiences using computerized reappraisal training. *Emotion, 12*(4), 778–784. https://doi.org/10.1037/a0024992.

Woud, M. L., Postma, P., Holmes, E. A., & MacKintosh, B. (2013). Reducing analogue trauma symptoms by computerized reappraisal training-Considering a cognitive prophylaxis? *Journal of Behavior Therapy and Experimental Psychiatry, 44*(3), 312–315. https://doi.org/10.1016/j.jbtep.2013.01.003.