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Lifetime adversity interacts with peritraumatic data-driven processing to predict intrusive memories

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ABSTRACT

Background and objectives: Although most trauma survivors experience some intrusive recollections of the traumatic event, only few subsequently develop posttraumatic stress disorder (PTSD). A well-established proximal risk-factor predictive of post-trauma psychopathology is peritraumatic cognitive processing. Another, more distal risk-factor is pre-trauma lifetime adversity. The present experimental analogue study tested the hypothesis that pre-trauma lifetime adversity interacts with peritraumatic perceptual (i.e., data-driven) processing to predict intrusive memory development.

Methods: Fifty-three young adult women (non-clinical sample) indicated how much data-driven and conceptual processing they had engaged in while watching aversive film-clips (i.e., analogue trauma). On the subsequent three days, they reported intrusions of those clips. Moderation analyses tested for an interaction effect between lifetime adversity and data-driven processing in predicting intrusion load (number of intrusions weighted for their overall distress).

Results: Increased data-driven processing predicted intrusion load primarily in individuals reporting more than three lifetime adversities, explaining 55% of variance. No such relationship was found for conceptual processing.

Limitations: Present analogue findings have yet to be replicated in a clinical population. Moreover, the conceptual processing scale was restricted by low internal consistency.

Conclusion: Present findings support the idea that intrusions are the result of poorly elaborated and primarily perceptually-formed memory traces; however, this was primarily the case in vulnerable individuals reporting several lifetime adversities. Results replicate the importance of peritraumatic processing in intrusion development but additionally point to a moderating effect of lifetime adversity.

1. Introduction

While many individuals experience a traumatic event, only a minority develops posttraumatic stress disorder (PTSD; Kessler et al., 2017). Following trauma, most individuals report involuntary re-experiencing of the event; these so-called intrusions typically subside after few weeks. Some individuals, however, experience persisting intrusions, representing a main symptom of PTSD. Several theories of PTSD propose a link between peritraumatic cognitive processing and intrusive re-experiencing (i.e., intrusions).

Such models include Ehlers and Clark (2000) cognitive model of PTSD, the dual representation theory by Brewin (2001; 2010; Brewin & Holmes, 2003), and Conway's model of autobiographical memory (Conway & Pleydell-Pearce, 2000). Although these models differ in some respect, they converge in proposing multiple pathways that underlie memory formation. On the one hand, these models posit that extremely aversive, traumatizing events are only weakly processed and primarily encoded in terms of sensory, perceptual information (i.e., enhanced data-driven processing, DDP; e.g., "I could not think clearly''). On the other hand, they propose that such events are processed in a less organized-way, with less encoding of the trauma narrative and verbal memories (i.e., reduced conceptual processing, CCP; e.g., "I knew exactly what was happening"). It is theorized that this shift to peritraumatic lower-level sensation-based processing (DDP) results in disorganized and fragmented trauma memories that are, on the one hand, automatically retrieved in response to trauma-related perceptual cues (Brewin, Gregory, Lipton, & Burgess, 2010; Conway, 2005); on the other hand, these memories lack contextual/autobiographical

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information and thus are hard to be intentionally retrieved (Ehlers & Clark, 2000). Intrusions can thus be understood as poorly elaborated autobiographical memory traces.

The idea that increased DDP during trauma is linked to PTSD symptomatology has been supported by both clinical and analogue studies. Clinical studies have shown that high peritraumatic DDP is associated with more PTSD symptomatology in adults (e.g., Ehlers et al., 2010; Ehring, Ehlers, Cleare, & Glucksman, 2008; Halligan, Michael, Clark, & Ehlers, 2003; Murray, Ehlers, & Mayou, 2002), as well as children and adolescents (Ehlers, Mayou, & Bryant, 2003; McKinnon, Nixon, & Brewer, 2008; Meiser-Stedman et al., 2019). However, as clinical studies are bound to retrospective assessment of peritraumatic processes, they are prone to reporting biases (Ebner-Priemer & Trull, 2009). Overcoming this shortcoming, analogue studies assess DDP in real time, using highly aversive film-clips as trauma analogue (James et al., 2016). In line with clinical findings, analogue studies linked high DDP to more intrusions (e.g., Halligan, Clark, & Ehlers, 2002; Laposa & Rector, 2012; Morina, Leibold, & Ehring, 2013; Regambal & Alden, 2012; Sachschal, Woodward, Wichelmann, Haag, & Ehlers, 2019). Although it has been proposed that DDP and CCP are inversely related (Johnston & Hawley, 1994), few studies have assessed effects of CCP on intrusions. In a study with PTSD patients, analysing trauma narratives, increased CCP following treatment was linked to better treatment outcome (Kindt, Buck, Arntz, & Soeter, 2007); in two analogue studies, high CCP (compared to DDP) was linked to decreased intrusions (Halligan et al., 2002; Kindt, van den Hout, Arntz, & Drost, 2008). In summary, increased DDP is a well-established proximal risk-factor playing a key role in PTSD development, whereas evidence for CCP is scarce.

In terms of pre-traumatic risk factors, lifetime adversity constitutes a distal risk-factor that has consistently been linked to PTSD development upon re-exposure to trauma (e.g., Breslau, Chilcoat, Kessler, & Davis, 1999; Kolassa & Elbert, 2007) and to increased PTSD-symptomatology (Briere, Agee, & Dietrich, 2016; Cloitre et al., 2009). Research indicates that PTSD-symptomatology following trauma increases with the number of adversities fulfilling DSM criterion A (Kilpatrick et al., 2013; physical and sexual assault only: Follette, Polusny, Bechtle, & Naugle, 1996). Critically, studies suggest that individuals with four or more adversities (including childhood abuse and other potentially traumatic events) are at particular risk for developing pathology (Hughes et al., 2017; Karam et al., 2014). Individuals above a threshold of four lifetime adversities may be particularly prone to the detrimental effects of other proximal risk factors following trauma.

Although of potential interest, little research has investigated the interplay between distal (like lifetime adversity) and proximal risk factors (like DDP; see review by Ford, Grasso, Elhai, & Courtois, 2015). Therefore, the present study investigated whether the relationship between peritraumatic processing (DDP, CCP) of analogue-trauma and the development of intrusions changes as a function of lifetime adversity. We used aversive film-clips as analogue-trauma and assessed intrusions ambulatorily on three consecutive days. We hypothesized that high DDP during aversive film-viewing increases intrusions after analogue-trauma. With past research pointing to a risk threshold of four lifetime adversities, we expected that for individuals above this threshold, increased DDP to have a particularly detrimental effect on PTSD-like symptomatology, while having little effect on individuals with low adversity. Secondary analyses investigated if increased CCP would have the reverse effect.

2. Methods

2.1. Participants

The final non-clinical sample (after exclusion of five participants due to missing questionnaire data and two participants due to technical recording problems) consisted of 53 women (age: $M = 22.90$ years, $SD = 4.18$). Exclusion criteria were any mental disorder, psychotropic medication, serious medical conditions, or history of traumatic head injury. As the experimental session was conducted in the magnetic resonance imaging (MRI) scanner (see Rattel et al., 2019; Miedl et al., 2020 for MRI results), additional exclusion criteria were pregnancy, ferromagnetic implants, other non-removable metal objects, and claustrophobia. The sample was controlled for extensive violent media consumption (<3 times a week) and poor sleep quality (≤7 on the Pittsburgh Sleep Quality Index; Buysse, Reynolds III, Monk, Berman, & Kupfer, 1989). The study was approved by the local ethics committee; all participants provided informed consent.

2.2. Materials and procedure

Questionnaire data. One week before the experimental session, participants completed the Center for Epidemiologic Studies *Depression* Scale (CESD; Radloff, 1977; German version: Meyer & Hautzinger, 2001) and the *State-Trait-Anxiety* Inventory (STAI, German version: Laux, Glanzmann, Schaffner, & Spielberger, 1981).

Participants watched aversive film-clips (for details, see below) and then completed the *Cognitive Processing Questionnaire* assessing data-driven (DDP) and conceptual processing (CCP) of traumatic material (e.g., Halligan et al., 2003; Murray et al., 2002); participants were instructed to relate the questions to the previously seen film-clips. Eight DDP items assessed the degree of sensory, surface-level processing, with good internal consistency ($\alpha = .86$). Six CCP items assessed processing of the meaning of the situation; though, this scale revealed poor internal consistency ($\alpha = .58$). Participants rated the items on a five-point scale from "*not at all (0)*" to "*very strongly (4)*". Sum scores are reported.

At the end of the study, participants filled out the *Traumatic Life Experiences* questionnaire (TLEQ, Kubany et al., 2000; German version: Teegen, 2003), assessing 22 types of traumatic events that may meet the DSM-5 PTSD criterion A definition. Participants state the frequency of the endorsed event (seven-point scale, *'never', '1'-'5', 'more than five times' (coded as 6)*) and the associated distress. A sum score was computed to assess the overall occurrence of lifetime adversity.

Film-viewing. An adapted version of the trauma film paradigm was shown to participants in the MRI scanner, consisting of six different 16s duration aversive and six neutral film-clips. Clips were presented twice in pseudorandom order (see Rattel et al., 2019).

Intrusive memories. At the end of the experimental session, participants were instructed to report any film-related intrusions for the rest of the present and the three consecutive days in an event-based manner using a customized e-diary smartphone application (Rattel, Grünberger, et al., 2019). Intrusions were defined as recurring images or thoughts about the film, but also as recurring thoughts or feelings that had been present during watching (Intrusive Memory Questionnaire, IMQ; Zetsche, Ehring, & Ehlers, 2009). Only involuntary memories and no deliberate recall should be recorded; intrusions during the night (e.g., dreams, during awakenings) were counted as well. Each intrusion was rated in terms of the associated distress from 0 "*not at all*" to 100 "*extremely distressing*" (visual-analogue-scale). If no intrusion was reported for a respective day, intrusion frequency and distress were set to zero for this day.

2.3. Statistical analyses

In line with previous publications (Rattel, Miedl, et al., 2019; Rattel, Wegerer, et al., 2019), we were particularly interested in the frequency of intrusions weighted for their distress (frequency × distress), subsequently referred to as intrusion load (see Supplements for results on frequency and distress). A two-step hierarchical regression analysis was computed: first, analyses checked for an effect of lifetime adversity (*distal risk-factor*) and peritraumatic processing (DDP, CCP; *proximal risk-factors*) on intrusion load; second, their interaction term was added. Predictors were mean centered and R^2 is reported as effect size. We tested for a significant R^2 change from step one to step two. Bonferroni

correction was used for DDP and CCP, adjusting the α-level to .025. All analyses were computed using IBM-SPSS-20. For interaction effects, the Johnson-Neyman technique was used to compute regions of significance (Hayes & Rockwood, 2017). Zero-order correlations between study variables are presented for descriptive purpose.

3. Results

3.1. Sample characteristics

Participants reported 4.98 lifetime adversities on average (*median* = 2, *SD* = 5.98, *range* = 0–21; see Supplements Fig. S1 for the frequency distribution of the number of reported traumatic events and Fig. S2 for the frequency of different trauma types). Across the three-day assessment, they reported 1.55 intrusions (*SD* = 2.02), with a mean distress level of 11.58 (*SD* = 14.69, scale 0–100). Trait anxiety (*M* = 35.43, *SD* = 7.13) and depressive symptoms (*M* = 9.94, *SD* = 6.08) were within normal range.

3.2. Zero-order correlations between study variables

Lifetime adversity was significantly correlated with intrusion load. Moreover, DDP (*M* = 11.96, *SD* = 6.06) and CCP (*M* = 15.04, *SD* = 3.54) were significantly correlated. None of the other correlations reached significance (Table 1).

3.3. Hierarchical regression analysis of lifetime adversity and DDP on intrusion load (see Table 2)

Step 1. Both lifetime adversity and DDP were significant predictors for intrusion load.

Step 2. Adding the interaction term between lifetime adversity and DDP resulted in a significant increase in R^2, with this model explaining 55% of the variance in intrusion load. As shown in Fig. 1, intrusion load increased with increased DDP only in women reporting more than three lifetime adversities (*N* = 21).

3.4. Hierarchical regression analysis of lifetime adversity and CCP on intrusion load (see Table 3)

Step 1. Lifetime adversity, but not CCP, was a significant predictor for intrusion load.

Step 2. Using the Bonferroni-adjusted α-level, no significant interaction effect was found for CCP. Although at trend, intrusion load increased with increased CCP only in women reporting more than 16 lifetime adversities (only four participants exceeded this threshold). Thus, the relationship between CCP und intrusion load was only significant in individuals reporting more than 16 lifetime adversities and this was only the case for four of our participants.

4. Discussion

The present study investigated to what degree the relationship between peritraumatic data-driven processing (DDP) and intrusion load changes as a function of lifetime adversity. Results revealed that the more DDP participants engaged in, the more intrusion load they reported; importantly, this was particularly the case for individuals reporting more than three lifetime adversities. Results showed that a model accounting for the interactive relationship between lifetime adversity and DDP explained 54.5% of variance in intrusion load. When intrusion load was split into frequency and distress, results were mainly explained by intrusion distress (see Supplements). Thus, present findings indicate that individual differences in cognitive processing of acute stress are an important risk-factor contributing to the onset of PTSD-like symptoms, particularly on a background of elevated pre-trauma lifetime adversity.

Present findings highlight the joint role of lifetime adversity and peritraumatic processing in developing distressing intrusions. In line, past research proposed lifetime adversity as an important distal pre-traumatic risk factor for PTSD development upon exposure to trauma (Breslau et al., 1999; Cloitre et al., 2009) while others concluded that peritraumatic processing is the most robust proximal risk factor contributing to PTSD (Ford et al., 2015; Ozer, Best, Lipsey, & Weiss, 2003). The present study was the first to study the link between DDP and intrusions as a function of lifetime adversity.

For individuals with several lifetime adversities, present findings are in line with past clinical and analogue studies (e.g., Ehlers et al., 2010; Evans, Ehlers, Mezey, & Clark, 2007; Halligan et al., 2002). Individuals who primarily engaged in DDP, i.e., sensory-perceptual encoding (e.g., a loud scream; image of injury), were more likely to re-experience film--clips as distressing intrusions. In line with Ehlers and Clark's (2000) cognitive model and Brewin et al.'s (2010) dual-processing theory, this form of processing may have prompted poorly elaborated autobiographical memory traces. As a result, without the corresponding contextual and conceptual organization, individuals were less likely to incorporate the sensory memories into their broader autobiographical memory.

The present study revealed that DDP predicted intrusion load only when investigated jointly with lifetime adversity; compared to past studies, no zero-order correlation was found between DDP and intrusion load. In comparison to other analogue studies (Laposa & Rector, 2012; Sachschal et al., 2019), these differences may be explained by differences in duration and nature of film-clips. The present study used six different, short aversive clips, compared to others using one longer-lasting clip. It has been suggested that shorter film-clips may increase data-driven processing due to reduced context (Marks, Franklin, & Zoellner, 2019), which is in line with the relatively high average sum scores of DDP (11.96) in the present study (compared to Sachschal et al., 2019: 9.04 and Laposa & Rector, 2012: 6.37). Although no zero-order correlation between DDP and intrusion load was found, when including the interaction between lifetime adversity and DDP, R^2 increased by 22.5% (to a total R^2 = 54.5%, Table 3). This exceeds effect sizes for DDP predicting intrusions reported by previous analogue-studies not taking into account lifetime adversity ($R^2 \approx 0.14$; Laposa & Rector, 2012; Sachschal et al., 2019) and effect sizes for DDP reported by clinical studies ($R^2 \approx 0.07$ for PTSD-symptom severity: Murray et al., 2002; $R^2 \approx 0.31$ for intrusion qualities: Halligan et al., 2003). In any case, our interaction approach indicates that the relationship of DDP with intrusions is particularly strong in vulnerable individuals characterized by high lifetime adversity. Future studies should further investigate the relationship between DDP and lifetime adversity taking into account different intrusion outcomes as well as differences in film-clips.

Although DDP and conceptual processing (CCP) were inversely related (sharing ~23% of variance), no robust relationship was found for CCP with intrusion load. This contrasts with the few past studies that assessed CCP, linking increased CCP to fewer intrusions (Halligan et al., 2002; Kindt et al., 2007, 2008). In the present study, internal consistency for the CCP scale was low, contrasting with good internal consistency reported by Halligan et al. (2002), which may have reduced the potential to find meaningful associations. In addition, a review by Marks et al. (2019) pointed out that short film-clips may not be ideal to study

Table 1
Zero-order correlations (with *p*-levels) between study variables.

	Intrusion load	Lifetime adversity	DDP
Intrusion load	–	–	–
Lifetime adversity	.46[a]	–	–
DDP	.23	-.22	–
CCP	.12	.24	-.48[a]

[a] $p < .001$.

Table 2
Hierarchical regression analysis of lifetime adversity and DDP on intrusion load.

Step	Predictor	Unstandardized coefficients		Standardized coefficients		R^2	ΔR^2	ΔF
		B	*SE*	β	*p*			
1						.320	.320	11.76***
	Lifetime adversity	8.54	1.92	.53	<.001			
	DDP	5.41	1.90	.34	.006			
2						.545	.225	24.22***
	Lifetime adversity	11.63	1.71	.72	<.001			
	DDP	5.34	1.57	.34	.001			
	Interaction	1.47	.30	.51	<.001			

Note. DDP = data-driven processing; *SE* = standard error; Δ = change; *** = $p < .001$, ** = $p < .005$, * = $p < .025$.

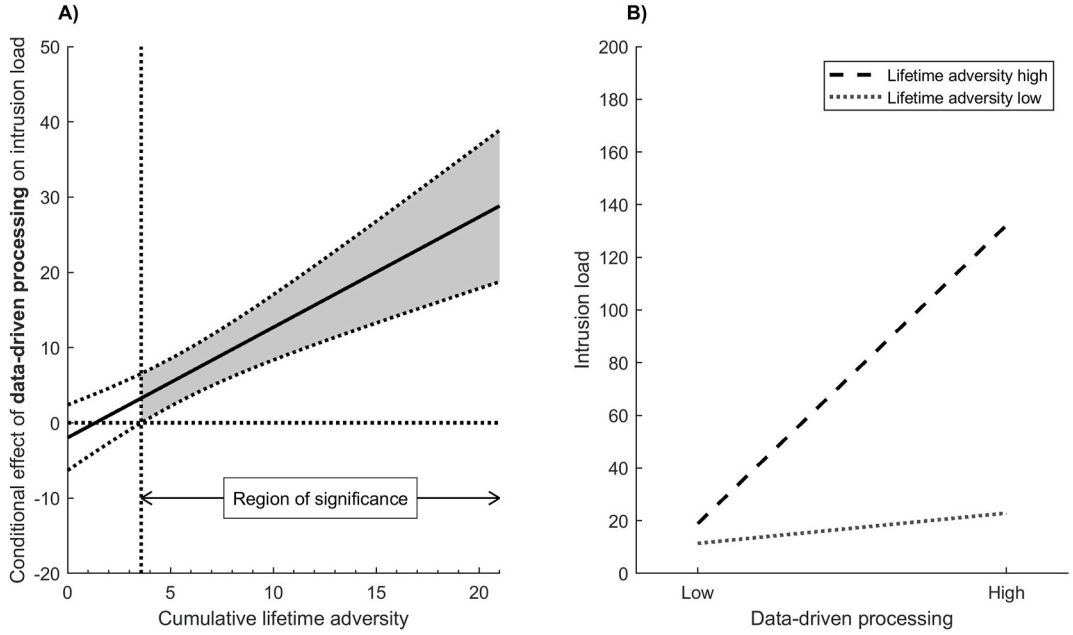

Fig. 1. A) A Johnson-Neyman plot. This plot displays the regions of significance for the interaction effect between lifetime adversity and DDP on intrusion load. The point estimate is marked by a solid line, and the upper and lower limit of the 95% confidence intervals (CIs) is marked by dotted lines. The slope of the linear regression estimate for DDP on intrusion load (conditional effect; y-axis) is plotted against the number of lifetime adversities (x-axis). When cumulative lifetime adversity exceeded a threshold of three (21 participants exceeded this threshold), the slope of DDP on intrusion load reached significance, as the CIs did not enclose the value of 0. The region of significance is marked in gray. Thus, the relationship between DDP und intrusion load was only significant in individuals reporting more than three lifetime adversities and this was the case for 21 of our participants. B) Interaction effect between lifetime adversity and DDP (low = 1*SD* below the mean; high = 1*SD* above the mean) in predicting intrusion load. The Johnson-Neyman technique was used to split the sample into participants reporting "high lifetime adversity" (>3 events) and those reporting "low lifetime adversity" (≤3 events).

Table 3
Hierarchical regression analysis of lifetime adversity and CCP on intrusion load.

Step	Predictor	Unstandardized coefficients		Standardized coefficients		R^2	ΔR^2	ΔF
		B	*SE*	β	*p*			
1						.209	.209	6.61**
	Lifetime adversity	7.32	2.08	.46	.001			
	CCP	.23	3.52	.01	.948			
2						.284	.075	5.13
	Lifetime adversity	6.23	2.06	.39	.004			
	CCP	.32	3.39	.01	.914			
	Interaction	1.30	.58	.28	.028			

Note. CCP = conceptual processing; *SE* = standard error; Δ = change; *** = $p < .001$, ** = $p < .005$, * = $p < .025$.

CCP due to reduced broader context. Therefore, future studies may need to revise the CCP scale and consider using longer film-clips. Moreover, different researchers used different scales/questionnaires to assess DDP and CCP (e.g., Kindt et al., 2007 used one bidirectional scale to assess CCP vs. DDP), which could further explain diverging findings. In summary, present findings support the idea that intrusions are the result of poorly elaborated and primarily perceptually formed memory traces. The role of CCP warrants more systematic research before firm conclusions can be drawn.

Clinically, shifting peritraumatic processing away from perceptual DDP to processing of meaning (CCP) may be one way to reduce the frequency of intrusions. Studies already showed that peritraumatic tasks

interfering with perceptual processing can reduce intrusions (Bourne, Frasquilho, Roth, & Holmes, 2010; Logan & O'Kearney, 2012). With regard to the present findings, future studies should investigate whether "high-risk" individuals with several lifetime adversities particularly benefit from an experimental manipulation fostering CCP over DDP before analogue-trauma.

Some limitations should be noted. First, the present sample consisted of women only and may not generalize to men, as women and men differ in peritraumatic unconditioned and conditioned responding, resulting in sex differences in intrusion frequency (Rattel, Wegerer, et al., 2019). Moreover, present analogue findings have yet to be replicated in a clinical population. Lastly, we believe that more mechanistic experimental research is needed to better understand the probably complex and interwoven pathways involved in the development of intrusions on the background of high lifetime adversity. Lifetime adversity may only be a proxy for alterations in several biological domains (e.g., alterations in HPA-axis, McCrory, De Brito, & Viding, 2010; increased allostatic load, Scheuer et al., 2018). Moreover, the pathways by which it imposes risk may involve maladaptive emotion regulation strategies, like low emotional acceptance (Cook et al., 2005), which in turn could interact with cognitive processing in predicting intrusions (e.g., Schierholz, Krüger, Barenbrügge, & Ehring, 2016).

5. Conclusion

The present study found an interaction effect between cumulative lifetime adversity and peritraumatic DDP in predicting intrusion load. Increased DDP was linked to analogue PTSD symptoms particularly in individuals reporting more than three lifetime adversities.

Authorship contribution

Julina A. Rattel: Conceptualization, Methodology, Formal analysis, Investigation, Writing - original draft. Stephan F. Miedl: Conceptualization, Methodology. Laila K. Franke: Writing - Review & Editing. Thomas Ehring: Writing - Review & Editing. Frank H. Wilhelm: Conceptualization, Methodology, Supervision, Writing - review & editing.

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Appendix A. Supplementary data

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