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Peritraumatic dissociation revisited: associations with autonomic activation, facial movements, staring, and intrusion formation

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ABSTRACT
Background: Peritraumatic dissociation is purported to emerge together with attenuated autonomic arousal, immobility, and staring. However, empirical evidence is scarce and heterogeneous. Moreover, it is still a matter of debate whether these responses predict intrusion formation.
Objective: The present trauma-analogue study examined associations between peritraumatic dissociation, autonomic activation, facial movements, staring, and intrusion formation.
Method: Seventy-one healthy women watched a highly aversive film, while autonomic activation (heart rate, respiratory sinus arrhythmia, skin conductance level), facial movements (temporal variations in corrugator electromyography), and staring (fixation duration, tracklength) were assessed. Afterwards, participants rated the intensity of dissociation during film viewing and reported intrusions and associated distress in a smartphone application for 24 hours.
Results: Peritraumatic dissociation was linked to higher autonomic arousal (higher heart rate and, on a trend-level, lower respiratory sinus arrhythmia), increased facial movements, and staring (lower tracklength). Peritraumatic dissociation, higher autonomic arousal (higher heart rate and lower respiratory sinus arrhythmia), staring (higher fixation duration), and, on a trend-level, more facial movements were linked to higher intrusion load (number x distress of intrusions) and together explained 59% of variance. Skin conductance level was neither linked to peritraumatic dissociation nor intrusion load.
Conclusions: Our results suggest that, at low-dissociation-levels observed in trauma-analogue studies, peritraumatic dissociation may occur together with heightened autonomic arousal and facial movements, indexing increased negative affect. Staring might, irrespectively of dissociation-levels, serve as objective marker for dissociation. Together, peritraumatic dissociation and its psychophysiological correlates might set the stage for later intrusion formation.

Revisión de la disociación peritraumática: asociaciones con la activación autonómica, los movimientos faciales, la mirada fija y la formación de intrusiones

Antecedentes: Se supone que la disociación peritraumática surge junto con la activación autonómica atenuada, la inmovilidad y la mirada fija. Sin embargo, la evidencia empírica es escasa y heterogénea. Además, sigue siendo objeto de debate si estas respuestas predicen la formación de intrusiones.
Objetivo: El presente estudio análogo al trauma examinó las asociaciones entre la disociación peritraumática, la activación autonómica, los movimientos faciales, la mirada fija y la formación de intrusiones.
Método: Setenta y una mujeres sanas vieron una película altamente aversiva mientras se evaluaba la activación autonómica (frecuencia cardíaca, arritmia sinusal respiratoria, nivel de conductancia de la piel), los movimientos faciales (variaciones temporales en la electromiografía del corrugador) y la mirada fija (duración de la fijación, longitud del seguimiento). Posteriormente, las participantes calificaron la intensidad de la disociación durante la visualización de la película e informaron sobre las intrusiones y la angustia asociada en una aplicación para teléfonos inteligentes durante 24 horas.
Resultados: La disociación peritraumática se relacionó con una mayor activación autonómica (mayor frecuencia cardíaca y, a nivel de tendencia, menor arritmia sinusal respiratoria), mayores movimientos faciales y mirada fija (menor duración del seguimiento). La disociación peritraumática, la mayor activación autonómica (mayor frecuencia cardíaca y menor arritmia sinusal respiratoria), la mirada fija (mayor duración de la fijación) y, en un nivel de tendencia, más movimientos faciales estaban vinculados a una mayor carga de intrusiones (número x angustia de intrusiones) y juntos explicaban el 59% de la varianza. El nivel de

HIGHLIGHTS
• In our trauma-analogue study, peritraumatic dissociation was related to higher autonomic arousal, more facial movements, and staring.
• These peritraumatic responses predicted the subsequent formation of distressing intrusions.

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⊕ Supplemental data for this article can be accessed here.

conductancia de la piel no se relacionó con la disociación peritraumática ni con la carga de intrusión.

Conclusiones: Nuestros resultados sugieren que, a niveles bajos de disociación observados en estudios de trauma análogos, la disociación peritraumática puede ocurrir junto con una mayor activación autonómica y movimientos faciales, lo que indica un aumento del afecto negativo. La mirada fija, independientemente de los niveles de disociación, podría servir como marcador objetivo de disociación. En conjunto, la disociación peritraumática y sus correlatos psicofisiológicos podrían sentar las bases para la formación posterior de intrusiones.

重新审视创伤性解离: 与自主神经激活, 面部运动, 凝视和闯入形成的关联

背景: 创伤性解离据称与减弱的自主神经激活, 不动和凝视一起出现。然而, 实证证据较少且具有异质性。此外, 这些反应是否预测闯入形成仍然是一个有争议的问题。

目的: 本创伤模拟研究考查了创伤性解离, 自主神经激活, 面部运动, 凝视和闯入形成之间的关联。

方法: 71 名健康女性观看了一部十分令人厌恶的电影, 同时评估了自主神经激活 (心率, 呼吸性窦性心律失常, 皮肤电导水平), 面部运动 (皱眉肌电图的时间变化) 和凝视 (注视持续时间, 轨迹长度) 。之后, 参与者评估了电影观看过程中的解离强度, 并在24 小时内使用智能手机应用程序报告了闯入和相关痛苦。

结果: 创伤后分离与更高的自主神经唤醒 (更高的心率, 及趋势水平的下呼吸道窦性心律不齐), 更多的面部运动增加和凝视 (更低的轨迹长度) 有关。 创伤后分离, 更高的自主神经唤醒 (更高的心率和下呼吸窦性心律不齐), 凝视 (更长的注视持续时间), 以及在趋势水平上, 更多的面部运动与更高的闯入载荷 (闯入的次数 x痛苦) 相关联解释了 59% 的方差。 皮肤电导水平既不与创伤性解离也不与闯入载荷有关。

结论: 我们的结果表明, 在创伤模拟研究中观察到的低解离水平下, 创伤性解离可能与表明负性情感增加的高度自主神经激活和面部运动并发。无论解离水平如何, 凝视可能都可以作为解离的客观标志物。总之, 创伤后解离及其心理生理学相关因素可能为以后的闯入形成奠定基础。

1. Introduction

During traumatic events, some individuals experience dissociative states such as depersonalization, derealization, amnesia, and detachment – a phenomenon called peritraumatic dissociation (Marmar et al., 1994). According to evolutionary models (Kozlowska, Walker, McLean, & Carrive, 2015; Schauer & Elbert, 2010), peritraumatic dissociation emerges together with attenuated autonomic arousal, immobility, and staring[1] in order to attenuate suffering and facilitate remaining still when fight-or-flight is not an option. By these means, the perpetrator might lose interest and the victim might survive. However, empirical research linking peritraumatic dissociation to attenuated autonomic arousal, immobility, and staring is inconclusive. Moreover, the relevance of these responses for subsequent intrusions, a hallmark symptom of posttraumatic stress disorder (PTSD), is still a matter of debate.

1.1. Peritraumatic dissociation, attenuated autonomic arousal, and immobility

Theoretically, peritraumatic dissociation emerges together with attenuated autonomic arousal and immobility (Schauer & Elbert, 2010). However, real-life-trauma studies yielded heterogenous results: Retrospectively assessed peritraumatic dissociation was either linked (Griffin, Resick, & Mechanic, 1997; Pole et al., 2006) or not linked (Kaufman et al., 2002; Nixon, Bryant, Moulds, Felmingham, & Mastrodomenico, 2005) to attenuated autonomic responses to trauma narratives. Similarly, retrospectively assessed peritraumatic dissociation was either linked (Abrams, Carleton, & Asmundson, 2012; Abrams, Nicholas Carleton, Taylor, & Asmundson, 2009; Maia et al., 2015) or not linked (Hagenaars, 2016) to concomitant experienced immobility.

Although important, these real-life-trauma studies are limited by their retrospective nature with inherent risk of memory biases (David, Akerib, Gaston, & Brunet, 2010) which might be especially high for dissociation as it can include amnesia, by studying posttraumatically re-elicited instead of peritraumatic autonomic responses, and by exploring subjective instead of objective peritraumatic immobility. Furthermore, it is important to note that, although evolutionary models primarily link dissociation to an autonomic shutdown and immobility, it is commonly assumed that dissociation is initially preceded by an acute stress response including heightened arousal and mobility (Kozlowska et al., 2015; Schauer & Elbert, 2010). Thus, one could also suspect an initially positive association between dissociation, arousal, and mobility at low-dissociation-levels, which might disappear at intermediate-dissociation-levels and turn negative at high-dissociation-levels. If so, real-life-trauma studies might particularly capture relations at intermediate- and high-dissociation-levels, but not at lower-dissociation-levels.

Thus, studies subjecting healthy participants to a stressful film functioning as trauma-analogue constitute an important venue to study lower-dissociation-levels. In

a first trauma-film study, peritraumatic dissociation was, however, again linked to lower heart rate (HR), but only in participants who also responded to separately presented startle trials with HR deceleration (Chou, La Marca, Steptoe, & Brewin, 2014). Hence, the association between peritraumatic dissociation and autonomic activation remains unclear and further trauma-analogue studies incorporating a comprehensive set of autonomic measures are needed. In addition, no trauma-analogue study has explored the link between dissociation and immobility so far and it remains unclear whether the link reported in real-life-trauma studies can be generalized to lower-dissociation-levels.

1.2. Peritraumatic dissociation and staring

In concordance with theoretical models, therapists anecdotally report staring in acutely dissociating patients (Kozlowska et al., 2015). Moreover, when healthy participants had to visually follow a moving red circle, higher overall dissociative symptoms tended to be linked to less eye-movements (Cardeña, Nordhjem, Marcusson-Clavertz, & Holmqvist, 2017). Indirect evidence also comes from experimental studies (Holmes, Brewin, & Hennessy, 2004; Lickel, Nelson, Lickel, & Deacon, 2008): Participants who intensely stared at a dot experienced higher state dissociation than control groups, which might even indicate a causal relationship between staring and dissociation. Altogether, clinical observations and related studies suggest a link between peritraumatic dissociation and staring. Yet, direct empirical evidence is lacking.

1.3. Peritraumatic responses and intrusion formation

As peritraumatic dissociation is assumed to interfere with information processing and affect memory formation (Brewin & Holmes, 2003), it has long been considered an important predictor for intrusion formation and the development of PTSD (Lensvelt-Mulders et al., 2008). However, methodological shortcomings of clinical studies hint at the possibility that this conclusion might be premature. For instance, some studies have been imprecise in their definition of peritraumatic dissociation and its temporal boundaries and might have also included chronic dissociative symptoms (Van Der Hart, Van Ochten, Van Son, Steele, & Lensvelt-Mulders, 2008). Moreover, current symptom levels might have biased retrospective reports of peritraumatic dissociation (David et al., 2010).

To overcome these issues, researchers conducted trauma-analogue studies: Spontaneous dissociation during trauma-film viewing either enhanced (Holmes et al., 2004: Studies 1&2; Kindt, Van den Hout, & Buck,

2005; Laposa & Rector, 2012; Regambal & Alden, 2009) or did not affect intrusion development (Holmes et al., 2004: Study 3; Hagenaars, van Minnen, Holmes, Brewin, & Hoogduin, 2008; Kindt & van den Hout, 2003). Some researchers also experimentally manipulated dissociation during trauma-film viewing and failed to replicate an influence on intrusion development (Holmes et al., 2004: Study 1; Holmes, Oakley, Stuart, & Brewin, 2006).

One explanation for these mixed findings could be that spontaneously emerging but not experimentally manipulated dissociation is accompanied by distinct psychophysiological patterns, including attenuated autonomic arousal and immobility, which may themselves contribute to intrusion formation (Holmes & Bourne, 2008). Indeed, in some studies, autonomic arousal was lower during trauma-film scenes later becoming intrusive (Chou et al., 2014; Holmes et al., 2004: Studies 1&2). However, other studies linked heightened autonomic arousal during trauma-film viewing to intrusion formation (Holmes et al., 2004: Study 3; Ripley, Clapp, & Beck, 2017) stressing the need for further investigation. Regarding immobility, an initial study supported a link between immobility and intrusions (Hagenaars et al., 2008): Healthy participants with both, hypnotically induced and deliberate immobility during trauma-film viewing, developed more intrusions than a control group. Yet, studies objectively assessing immobility and linking it to intrusion formation are lacking. Moreover, to date, no study has investigated the relation between staring, another potential correlate of dissociation, and intrusions.

1.4. The current study

The current study investigated associations between peritraumatic dissociation, autonomic arousal, immobility, and staring during trauma-film viewing as well as their relation to subsequent intrusion formation. As it has been shown that intrusions perceived as distressing are especially relevant for persistent PTSD (Michael, Ehlers, Halligan, & Clark, 2005; Steil & Ehlers, 2000), we were primarily interested in the number of intrusions weighed for their distress (intrusion load). Based on previous findings, we formulated directional hypotheses. However, to account for the inconclusiveness of empirical evidence, all tests were carried out two-sided.

Our first aim was to examine the association between peritraumatic dissociation and other peritraumatic responses. We tentatively expected that higher peritraumatic dissociation would be related to attenuated autonomic arousal (indicated by lower HR, higher respiratory sinus arrhythmia, RSA, and lower skin conductance level, SCL), less facial movements

(indicated by less temporal variation in corrugator muscle activity), and staring (indicated by higher fixation duration and shorter tracklength assessed with eye-tracking). However, at the low-to-moderate levels of dissociation commonly induced by trauma-films, these relationships may not emerge or even be the opposite.

Our second aim was to investigate the association between peritraumatic responses and intrusion formation. We tentatively predicted that higher peritraumatic dissociation, attenuated autonomic arousal, less facial movements, and staring would be linked to intrusion load.

2. Method

2.1. Participants

Seventy-two healthy women between 18 and 35 years participated in the study. Exclusion criteria were current self-reported cardiovascular, neurological, sleeping, and psychiatric disorders as well as ongoing psychotherapeutic treatment. Moreover, participants should not have experienced severe violence leading to severe distress, consume violent media more than three times a week, have a blood or injury phobia applying to film scenes, or have participated in other trauma-film studies. One participant terminated film-viewing due to high emotional reactivity, leaving a final sample of 71 participants.

For analyses including autonomic measures, participants who smoked more than 10 cigarettes/day ($n = 1$) or took medication or drugs affecting the sympathetic nervous system within 24 hours before the assessment ($n = 2$) were excluded. Participants with abnormal ECG ($n = 2$) were excluded from ECG analyses. Due to technical or organizational problems, some measures were not available for all participants (for details see Table 1).

As detailed in Table 1, participants were within normal ranges regarding trait dissociation measured by the Questionnaire of Dissociative Symptoms (QDS; Freyberger et al., 1998), trait anxiety measured by the State-Trait-Anxiety Inventory (STAI-T; German version by Laux, Glanzmann, Schaffner, and Spielberger, 1981), and current depressive symptoms measured by the Center for Epidemiological Studies Depression Scale (CES-D; German version by Hautzinger and Bailer, 1993).

2.2. Procedure

The study consisted of an online pre-assessment, one session in the lab, and an ambulatory monitoring of intrusions. During pre-assessment, demographic and psychometric variables were assessed. In the lab, participants were seated and electrodes were attached.

Table 1. Descriptive statistics on sample characteristics and primary variables.

	N	M	SD
Sample characteristics			
Age (years)	71	21.18	3.65
Education (years)	71	14.21	2.78
BMI (kg/m^2)	65	22.37	3.42
QDS (0–100)	70	8.33	6.91
STAI-T (20–80)	71	39.01	8.54
CES-D (0–60)	71	12.54	6.80
Primary variables			
PDEQ (0–28)	71	8.51	4.20
HR (bpm)	61	0.32	5.66
RSA (ms)	61	−0.35	0.60
SCL (µS)	66	0.60	0.65
RMSSD-EMG (µV)	68	0.66	0.72
Fixation duration (ms)	69	114.25	19.82
Tracklength (kpixel)	69	720.91	409.39
Intrusion load (0-infinite)	67	106.91	131.97

Clinical cut-off values are >13 for QDS (Rodewald, Gast, & Emrich, 2006), >44 for STAI-T (Ercan et al., 2015), and >23 for CES-D (Hautzinger & Bailer, 1993). For HR, RSA, SCL, and RMSSD-EMG, baseline-adjusted values are reported. BMI = Body Mass Index; QDS = Questionnaire of Dissociative Symptoms; STAI-T = State-Trait-Anxiety Inventory-Trait; CES-D = Center for Epidemiological Studies Depression Scale; PDEQ = Peritraumatic Dissociative Experiences Questionnaire; HR = heart rate; RSA = respiratory sinus arrhythmia; SCL = skin conductance level; RMSSD-EMG = root mean squared successive differences of electromyography-signal amplitude.

After eye-tracker calibration (framed as visual attention exercise) participants looked at a fixation cross for 7.5 minutes (resting baseline) and reported accompanying distress. Then, participants watched the trauma-film for 7.5 minutes (trauma-film), reported accompanying distress, and rated their level of peritraumatic dissociation. Last, participants installed an application on their smartphone and were instructed to monitor intrusions for the next 24 hours. As the study was part of a larger project, participants then returned to the lab, received one out of three interventions, and continued intrusion assessment for another six days (results will be described elsewhere). Participants provided informed consent in advance and were compensated with course credit or money. The study was approved by the local ethics committee.

2.3. Stimuli and measures

2.3.1. Trauma-film

As trauma-film, a 7.5-minute montage of sections of the film 'Irreversible' (Noé, 2002) was used. This film has been frequently used to model a traumatic experience in the lab and has been shown to successfully elicit negative emotions and intrusions (Arnaudova & Hagenaars, 2017). During the film, a woman is threatened and raped by a man in an underpass on her way home from a club. The film was presented on a 23.6″ monitor using E-Prime 2.0 (Psychology Software Tools, Sharpsburg, PA). In our study, the film elicited

more distress (M = 77.35, SD = 20.47) measured on a Visual Analogue Scale from *not distressing at all* (0) to *very distressing* (100) than the resting baseline (M = 19.49, SD = 22.60), $t(70)$ = 17.56, p < .001.

2.3.2. Peritraumatic dissociation

Peritraumatic dissociation was assessed with the Peritraumatic Dissociative Experiences Questionnaire (PDEQ; Marmar, Weiss, & Metzler, 1997; German version by Maercker, 1994). Participants indicated dissociative responses (i.e. derealization, depersonalization, and altered time sense) during and immediately after trauma-film viewing on a scale from *not at all* (0) to *extremely* (4). Following previous trauma-film studies (Kindt et al., 2005), three items of the 10-item PDEQ were not included, as they were not appropriate for film paradigms (e.g. *What was happening seemed unreal to me, like I was in a dream or watching a movie or play*). A sum score for the seven remaining items was calculated. As expected, peritraumatic dissociation was associated with trait dissociation (r = .28, p = .019, 95% BCa CI = [.02, .52]).

2.3.3. Autonomic activity and facial movements

Autonomic and facial muscle activity were recorded using a Porti 32-channel-amplifier and the software Polybench 1.3 (TMSi, Twente Medical Systems International, EJ Oldenzaal, Netherlands) with a sampling rate of 512 Hz, and further processed with the software ANSLAB 2.6 (Blechert, Peyk, Liedlgruber, & Wilhelm, 2016; Wilhelm, Grossman, & Roth, 1999).

2.3.3.1. Cardiovascular activity.

For electrocardiography, two disposable solid-gel snap electrodes (Ag/AgCl, 10 mm inner-diameter) were placed on the right upper sternum and lowest left rib. R-waves were detected automatically in ANSLAB, visually checked for occasional misdetections, ectopic beats, and artefacts, and manually edited if necessary. We computed two parameters: 1) As index of psychophysiological arousal driven by both sympathetic activation and vagal deactivation, we computed HR (in beats per minute, bpm). 2) As index of vagal activation, we used RSA operationalized as heart period variability related to respiration (in msec^2) and computed as the natural logarithm of power spectral density estimates in the high-frequency band (0.15–0.50 Hz).

2.3.3.2. Electrodermal activity.

We assessed electrodermal activity with a high-precision module (Becker Meditec, Karlsruhe, Germany). Two non-disposable 5 mm inner-diameter Ag/AgCI cup electrodes filled with isotonic gel (TD-246, MedCat, Klazienaveen, Netherlands) were placed on the middle phalanx of the index- and middle-fingers of the non-dominant hand. As index of sympathetic activation, we computed SCL (in μS).

2.3.3.3. Facial movements.

In the absence of a reliable measure of whole-body movements in subjects in a sitting posture, we assessed *musculus corrugator supercilii* activity using electromyography (EMG). Two non-disposable 2 mm inner-diameter Ag/AgCI cup electrodes filled with a mixture of electrode gel (MedCat, Klazienaveen, Netherlands) and Nuprep (Weaver and Company, Aurora, CO) were placed 1 cm apart from each other adjacent to the left eyebrow. After low-pass filtering, rectification, and resampling to 1 Hz, EMG-signal amplitude was calculated. As index for facial movements, i.e. temporal variation in facial muscular activity, we calculated the root of the mean squared successive differences of EMG-signal amplitude (RMSSD-EMG; in μV) which is a measure of variability that takes into account gradual shifts in mean (Von Neumann, Kent, Bellinson, & Hart, 1941). Since *m. corrugator supercilii* activity is an index of negative affect (Bradley & Lang, 2000), this index can also be interpreted as reflecting dynamic variations in facial negative affect expressions.

2.3.4. Staring

Eye-tracker data were recorded at a sampling rate of 120 Hz using the Tobii Pro X3-120 eye-tracker (Tobii Pro AB, Danderyd, Sweden). The eye-tracker was placed right below the visible area of the display. The distance between participants' eyes and the eye-tracker was 60–65 cm. First, single missing datapoints between valid datapoints were linearly interpolated. Second, data were upsampled to 1000 Hz using linear interpolation and mean coordinates based on data for both eyes were calculated. In case of data points with valid data for one eye only, the respective data were used instead. Then, data were processed using the *Robust Eye Movement Detection for Natural Viewing* (REMoDNaV) algorithm (Dar, Wagner, & Hanke, 2021). The algorithm was modified to take variations in the distance between participants' eyes and the eye-tracker over time into account, as the participants' heads were not fixated during testing. This was achieved by using recorded eye distances to update the algorithm parameter for conversion of pixel to visual degrees on a per-sample basis instead of assuming a fixed eye-to-screen distance. Two parameters were computed: 1) the mean fixation duration (in ms), with longer overall fixation duration indicating staring, and 2) the overall tracklength (in kpixel), with lower tracklength (i.e. less/smaller eye-movements and more/longer fixations) indicating staring.

2.3.5. Intrusions

Participants reported intrusive memories in an event-based manner using a customized e-diary smartphone application. Intrusions were defined as recurring images, thoughts, or sounds about the film, but also recurring thoughts or feelings that had been present during film viewing (Zetsche, Ehring, & Ehlers, 2009). It was emphasized that only involuntary memories without deliberate recall should be reported. Intrusions during dreams were also counted. Participants had to report the associated distress on a Visual Analogue Scale from *not at all* (0) to *extremely distressing* (100). Participants reported on average 3.03 intrusions (*SD* = 2.70) which were accompanied by an average distress-level of 36.17 (*SD* = 24.25). Akin to previous studies (Franke et al., 2021; Rattel, Miedl, et al., 2019), we operationalized intrusions as intrusion load (number x distress of intrusions).

2.4. Statistical analyses

For HR, RSA, SCL, and RMSSD-EMG, baseline-corrected values (trauma-film minus baseline) were computed to account for individual differences unrelated to the experimental manipulation. For fixation duration and tracklength, no baseline-correction was performed as participants were instructed to fixate a cross at the middle of the screen during resting baseline.

Statistical analyses were performed in IBM SPSS Statistics 25 (IBM Corp., Armonk, NY, USA) with the macro RLM (Darlington & Hayes, 2017) for regression analyses. All analyses were performed two-sided (α = .05). Effect sizes were evaluated following (Cohen, 1988). Sensitivity analyses were conducted with G*Power (Faul et al., 2007; 1-β = .80; α = .05): Overall, the study was able to reliably detect medium-to-large effects (r = .32-.35; f^2 = .28).

We computed Pearson correlations to investigate whether peritraumatic dissociation (PDEQ) co-occurs with attenuated peritraumatic autonomic arousal (i.e. lower HR, higher RSA, lower SCL), less facial movements (i.e. higher RMSSD-EMG), and staring (i.e. higher fixation duration, lower tracklength). Moreover, we computed Pearson correlations to investigate whether these peritraumatic responses are associated with intrusion load. Since all variables except HR and RSA were non-normally distributed (Kolmogorov-Smirnov<.05), we calculated bias corrected accelerated bootstrap confidence intervals.

To examine the predictive value of peritraumatic responses for intrusion load, we computed a multiple regression with all predictors entered at once. In order to compensate for heteroscedasticity, heteroscedasticity-consistent standard error estimators (HC3) were used (Hayes & Cai, 2007). No influential cases (Cook's distance > 1) emerged.

Table 2. Pearson correlations between peritraumatic dissociation and other peritraumatic responses.

	N	r	p	95% BCa CI
Autonomic activation				
HR	61	.32	.013*	[.06, .51]
RSA	61	−.22	.090[+]	[−.47, .04]
SCL	66	−.18	.159	[−.37, .10]
Facial movements				
RMSSD-EMG	68	.48	<.001***	[.27, .65]
Staring				
Fixation duration	69	.18	.141	[−.03, .38]
Tracklength	69	−.24	.049*	[−.38, −.08]

For HR, RSA, SCL, and RMSSD-EMG, baseline-adjusted values were used. Confidence intervals are based on 10,000 bootstrap samples. BCa CI = bias corrected accelerated confidence intervals; HR = heart rate; RSA = respiratory sinus arrhythmia; SCL = skin conductance level; RMSSD-EMG = root mean squared successive differences of electromyography-signal amplitude.
[+]$p \le .10$, *$p \le .05$, **$p \le .01$, ***$p \le .001$.

For exploratory purposes, Pearson correlations between peritraumatic responses and intrusion frequency/distress are reported in the supplements.

3. Results

3.1. Peritraumatic dissociation and other peritraumatic responses

Correlations between peritraumatic dissociation and other peritraumatic responses are summarized in Table 2 and displayed graphically in the supplements. Contrary to our tentative predictions, dissociation was associated with higher HR and descriptively correlated with lower RSA, but this correlation just missed statistical significance. No association with SCL emerged. Surprisingly, dissociation was also associated with higher RMSSD-EMG. In line with our predictions, dissociation was associated with lower tracklength. However, it was not linked to fixation duration. While the associations of dissociation with HR and RMSSD-EMG had medium-to-large effect sizes, associations with RSA and tracklength were small-to-medium.

3.2. Peritraumatic responses and intrusion formation

Correlations between peritraumatic responses and intrusion load are summarized in Table 3 and displayed graphically in the supplements. As expected, dissociation was associated with higher intrusion load. Contrary to our predictions, higher HR and lower RSA were associated with higher intrusion load. Yet, SCL was not linked to intrusion load. Surprisingly, higher RMSSD-EMG descriptively correlated with higher intrusion load as well, but this correlation just missed statistical significance. Higher fixation duration was related to higher

Table 3. Pearson correlations between peritraumatic responses and intrusion load.

	N	r	p	95% BCa CI
Dissociation				
PDEQ	67	.47	<.001***	[0.23, 0.63]
Autonomic activation				
HR	58	.67	<.001***	[0.45, 0.82]
RSA	58	−.46	<.001***	[−0.64, −0.17]
SCL	62	.01	.920	[−0.19, 0.21]
Facial movements				
RMSSD-EMG	65	.21	.089+	[−0.05, 0.47]
Staring				
Fixation duration	65	.28	.024*	[0.11, 0.44]
Tracklength	65	−.12	.333	[−0.29, 0.06]

For HR, RSA, SCL, and RMSSD-EMG, baseline-adjusted values were used. Confidence intervals are based on 10,000 bootstrap samples. BCa CI = bias corrected accelerated confidence intervals; PDEQ = Peritraumatic Dissociative Experiences Questionnaire; HR = heart rate; RSA = respiratory sinus arrhythmia; SCL = skin conductance level; RMSSD-EMG = root mean squared successive differences of electromyography-signal amplitude.
+$p \leq$ .10, *$p \leq$ .05, **$p \leq$ .01, ***$p \leq$ .001.

intrusion load, but tracklength was not. While the associations of dissociation, HR, and RSA with intrusion load were medium-to-large, the associations of RMSSD-EMG and fixation duration with intrusion load were small-to-medium.

To estimate the predictive value of peritraumatic responses for intrusion load, a multiple regression was computed: Together, peritraumatic responses accounted for 59% of variance in intrusion load, $F(57) = 3.59$, $p = .003$ (for details, see supplements).

4. Discussion

The aim of the present study was twofold: First, we investigated whether peritraumatic dissociation is accompanied by attenuated autonomic arousal, immobility, and staring. Second, we examined whether these peritraumatic responses predict subsequent intrusion formation.

4.1. Peritraumatic dissociation linked to heightened autonomic arousal and mobility

Peritraumatic dissociation was linked to heightened autonomic arousal and increased mobility in our trauma-analogue study, whereas in previous real-life-trauma studies, dissociation was linked to attenuated autonomic arousal and immobility (Abrams et al., 2012, 2009; Griffin et al., 1997; Maia et al., 2015; Pole et al., 2006). As EMG corrugator activity could also index negative emotions (Bradley & Lang, 2000), our results might also suggest an association between dissociation and more negative emotions, which is in contrast to previous real-life-trauma studies linking dissociation to emotional numbing (Hopper, Frewen, Sack, Lanius, & van der Kolk, 2007).

One explanation for these conflicting findings might be that, as suggested by Schauer and Elbert (2010), the relationship between dissociation, autonomic arousal, mobility, and negative emotions follows an inverted-U-shape (see Figure 1): Initially (i.e. at low-dissociation-levels), dissociation might emerge together with an acute stress response including heightened autonomic arousal, mobility and negative emotions. Later (i.e. at intermediate-dissociation-levels), this relationship might disappear. Finally (i.e. only at high-dissociation-levels), intensifying dissociation might be linked to an increasing autonomic shutdown, immobility, and emotional numbing. Our trauma-analogue study with rather low-dissociation-levels (see Table 1) probably primarily captured the former link, whereas real-life-trauma studies with higher-dissociation-levels (Abrams et al., 2012, 2009; Griffin et al., 1997; Hopper et al., 2007; Maia et al., 2015; Pole et al., 2006) might have captured the latter. Probably, studies with different dissociation-levels within participants would provide a clearer picture and be a more direct test of this proposed relationship.

As our study was merely observational, we can only speculate about causalities. Since dissociation is assumed to particularly emerge in stressful situations (Marmar et al., 1994) and during bodily exercises (Lickel et al., 2008), we tentatively propose that during our trauma-analogue study, negative affect accompanied by heightened autonomic arousal and mobility might have facilitated dissociative experiences. Meanwhile, evolutionary theorizing suggests that dissociation itself might protect from overwhelming negative affect (Schauer & Elbert, 2010). Hence, broadening the conceptualization of dissociation, one might understand dissociation as a 'safety switch': When too much current runs through the circuits,
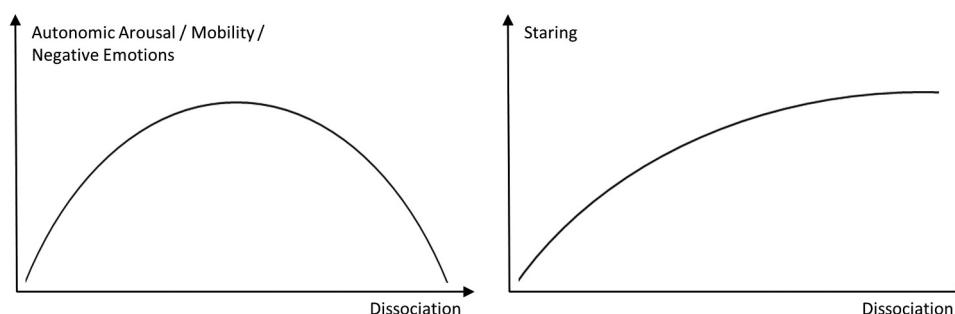
Figure 1. Illustration of the proposed relationship between dissociation and other peritraumatic responses.

dissociation arises and counteracts damage. On these grounds, future studies should consider this dynamic and nonlinear interplay when forming predictions about correlates of dissociation.

In our study, associations between peritraumatic dissociation and autonomic activation emerged for HR and revealed a non-significant descriptive trend for RSA (indexing vagal activity), but not SCL (indexing sympathetic activity). This might imply that dissociation is particularly linked to vagal withdrawal (leading to higher HR) and less to sympathetic arousal, which could guide hypothesis building for future research. Yet, as trauma-films have been found to differ from one another regarding autonomic responses (Arnaudova & Hagenaars, 2017), replications with other trauma-films are needed.

4.2. Peritraumatic dissociation linked to staring

Our study was the first to empirically demonstrate a link between peritraumatic dissociation and staring, which is consistent with theoretical models on peritraumatic dissociation and clinical anecdotes about acutely dissociating patients (Kozlowska et al., 2015; Schauer & Elbert, 2010). Thus, while the relation between dissociation, autonomic arousal, mobility, and emotions might be nonlinear and depend on dissociation-level, staring might, independently of dissociation-level, constitute an objective and linear marker for dissociation (see Figure 1). This might be especially useful as amnesia can also be part of dissociative responding (Marmar et al., 1994), which might limit the validity of self-reported dissociation. Contrary to physiological and emotional changes which might, as outlined above, be understood either as antecedents or consequences of dissociation, staring might occur in parallel with dissociation, together restricting information intake to attenuate suffering (Schauer & Elbert, 2010). Anyway, as our study was the first to directly investigate this topic, further trauma-analogue and clinical studies are urgently needed before strong conclusions can be drawn. It is important to note that while both eye-tracking indices were consistent in this, a significant association between dissociation and staring only emerged for tracklength. Considering the small association between fixation duration and dissociation, this might be due to the limited sensitivity of the current study, which was only able to reliably detect medium-to-large effects. Hence, future studies in larger samples are urgently needed. Moreover, it might as well be plausible that staring performs as better index for dissociation at higher dissociation-levels. Thus, assessing staring in acutely dissociating patients might constitute another promising venue for future research.

4.3. Peritraumatic dissociation and its correlates linked to intrusion formation

In line with previous trauma-film studies (Holmes et al., 2004: Studies 1&2; Kindt et al., 2005; Laposa & Rector, 2012; Regambal & Alden, 2009), peritraumatic dissociation predicted subsequent intrusion load in our study. This supports the theoretical assumption that peritraumatic dissociation interferes with the formation of an organized, contextually embedded trauma-memory and hence increases the risk of distressing involuntary recollections (Brewin & Holmes, 2003). However, studies experimentally manipulating peritraumatic dissociation did not find effects on intrusion formation (Holmes et al., 2004: Study 1; Holmes et al., 2006) which has raised doubt about the causal role of dissociation. Thus, it has been suggested that correlates of dissociation, which have not been targeted in dissociation manipulations, might contribute to intrusion formation (Holmes & Bourne, 2008). In our study, correlates of peritraumatic dissociation (i.e. autonomic arousal, staring, and, on a trend-level, mobility) were indeed linked to intrusion load as well. Thus, one could interpret our findings as initial evidence for this viewpoint and dissociation could be considered as top of the iceberg with underlying psychophysiological and behavioural layers contributing to its detrimental effect. However, differentiating between causal predictors of intrusion formation and third variables is beyond the scope of our study design and needs to be addressed in experimental studies.

In our study and some previous trauma-film studies (Holmes et al., 2004: Study 3; Ripley et al., 2017), higher peritraumatic autonomic arousal was linked to intrusion formation. This supports the theoretical notion that higher peritraumatic autonomic arousal alters the contextualization of incoming information and thereby contributes to the development of a fragmented memory, which is prone to involuntary retrieval (Brewin & Holmes, 2003). However, conversely, some trauma-film studies have linked attenuated peritraumatic autonomic arousal to intrusion formation (Chou et al., 2014; Holmes et al., 2004: Studies 1&2). As trauma-films differ greatly regarding evoked autonomic responses (Arnaudova & Hagenaars, 2017), it could be that the trauma-films in those studies did only evoke orienting responses marked by HR decreases but not defensive or stress responses marked by HR increases, which might have blurred associations with intrusions.

We did not replicate the link between peritraumatic immobility and intrusion formation implicated by a study reporting an effect of experimentally manipulated whole-body immobility on intrusion formation (Hagenaars et al., 2008). Instead, a non-significant

descriptive trend for an association between more facial mobility and intrusion load emerged. It could be that facial movements differ qualitatively from whole-body movements, as they also reflect emotional activation (Bradley & Lang, 2000) which is assumed to inhibit the contextualization of trauma-memories and thereby promote intrusion formation (Brewin & Holmes, 2003). However, it could also be that not objective but subjective immobility, i.e. the subjective feeling of inescapability evoked by immobility manipulations, is crucial for intrusion formation. Hence, future studies will need to re-examine this issue with objectively assessed whole-body movements.

Interestingly, staring was also related to intrusion load. Staring is assumed to be part of the sensory deafferentation taking place during traumatic events to shield victims from unpleasant sensations by limiting visual input (Schauer & Elbert, 2010). By these means, staring could, just like dissociation, interfere with effective memory encoding and promote intrusion development (Brewin & Holmes, 2003). Yet, as our study was the first to explore this link, replication is urgently needed. Moreover, it should be noted that the association between staring and intrusion load only emerged for one out of two staring indices which might, as indicated above for their relationship with dissociation, be due to limited study protocol or marker sensitivity.

To account for the relevance of intrusion distress for the persistence of PTSD (Michael et al., 2005; Steil & Ehlers, 2000) and to reduce alpha inflation, we, akin to previous studies (Franke et al., 2021; Rattel, Miedl, et al., 2019), operationalized intrusion formation as the total number of intrusions weighted for their average distress (intrusion load). Yet, to ensure compatibility with previous research focusing solely on intrusion frequency, we conducted secondary analyses on intrusion frequency and distress separately. As peritraumatic dissociation was linked to intrusion load and intrusion distress but not intrusion frequency, one could assume that it especially relates to more clinically relevant, distressing intrusions. In contrast, higher autonomic activation seems to be relevant for both, non-distressing intrusions captured by intrusion frequency as well as clinically relevant intrusions captured by intrusion load and intrusion distress. Considering facial movements and staring, an association with intrusion load but no associations with intrusion distress or frequency emerged, except for a descriptive positive association between fixation duration and intrusion distress. Overall, these results indicate a comparatively high sensitivity of intrusion load further promoting its use as primary outcome in trauma-analogue studies.

4.4. Limitations

First, analogue trauma is less severe than real-life trauma. Yet, it is able to reproduce many aspects of peri- and posttraumatic responses and thus is considered a valid method for studying traumatization experimentally under controlled conditions in the laboratory (Holmes & Bourne, 2008). Second, our immobility measure lacks specificity as it also indexes temporal variations in negative emotions. Third, we did only assess intrusions for 24 hours, which limits the generalizability of our findings. Future studies may investigate the influence of dissociation on the persistence of intrusions over several days. Fourth, due to time and monetary restrictions, this study only included female participants, which does not allow for generalization to men, especially as gender has been shown to affect intrusion formation (Rattel, Wegerer, et al., 2019; Zetsche et al., 2009). Fifth, some effects might have failed to reach significance due to the limited sensitivity of our study which was only able to reliably detect medium to large effects.

4.5. Conclusions

Our findings suggest that, at low-to-moderate dissociation-levels, peritraumatic dissociation might be linked to higher autonomic arousal, mobility, and negative emotions. Together with theoretical models and clinical reports, our findings hint at the possibility that staring might, across the entire dissociation continuum from very mild to severe dissociation, serve as an objective marker for dissociation in a rather linear fashion. Together, peritraumatic dissociation and some of its here investigated correlates might serve as early warning signals for the formation of distressing intrusions and thus warrant attention in clinical settings.

Notes

1. Please note that while some authors describe attenuated autonomic responses, immobility, and staring as subcomponents of dissociation (Schauer & Elbert, 2010), others treat them as distinct components of threat responses (Kozlowska et al., 2015). Thus, to enhance readability, we use the term dissociation only for the mentioned subjective experiences.

Data availability statement

As participants did not provide consent to make raw data publicly available, data are, in conjunction with an appropriate data sharing agreement, available on request from SKD.

Disclosure statement

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