The Differential Effects of Trauma-Focused Interventions on Voluntary and Involuntary Retrieval of Distressing Memories: Insights from Analogue Studies

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General Abstract

Post-Traumatic Stress Disorder (PTSD) is marked by recurrent, distressing memories of traumatic events. Trauma-focused psychological interventions aim to alleviate the distress caused by intrusive memories, but their objective is not to erase the traumatic memory entirely. For instance, a police officer might need to recall details of a past operation to improve future risk assessments, or a survivor of physical assault may require accurate memory recall to pursue legal action against their perpetrator. The effectiveness of trauma-focused interventions in alleviating intrusive memories is well-documented; however, their impact on voluntary memory remains poorly understood. Clinical theories propose that these interventions should selectively reduce intrusive memories, but preserve – or even enhance – the voluntary recall of event details, leading to more coherent and organized memory reports. In contrast, experts in legal psychology raise concerns that these interventions might unintentionally compromise the factual accuracy of voluntary memories. Interventions incorporating imagery-based techniques, such as Imaginal Exposure (IE), Eye Movement Desensitization and Reprocessing (EMDR), and Imagery Rescripting (ImRs), have been at the center of this debate. The primary aim of this thesis was to bridge these contrasting perspectives by systematically examining the effects of IE, EMDR and ImRs on both involuntary and voluntary retrieval of distressing memories across three analogue studies conducted with healthy participants.

Study I and *II* assessed the effects of these interventions on experimentally induced memories, allowing for experimental control over memory content and assessment of memory accuracy. In *Study I*, a distressing memory was induced in $N = 265$ participants, using the Trier Social Stress Test (TSST). The following day, participants received IE, EMDR, ImRs, or no intervention (NIC). One week later, the accuracy of voluntary memory for the TSST was assessed using a cued recall task. Involuntary memories of the TSST were assessed via an app-based intrusion diary. Results indicated no group differences in memory accuracy, suggesting that none of the interventions impaired or enhanced memory accuracy compared to NIC. Regarding involuntary memory, none of the interventions significantly reduced intrusion frequency; however EMDR and IE reduced intrusion load (intrusion frequency weighted by distress). Although these findings are encouraging from a clinical perspective, they leave open the possibility that certain factors in the clinical application of these interventions might still increase the risk of memory distortions.

Study II examined potential risk conditions under which ImRs might lead to memory distortions, focusing on whether instructions encouraging vivid and detailed imagination of changes to a memory increase this risk, and whether unclear or incomplete memories are particularly vulnerable. In a three-day online trauma film paradigm, a distressing memory was induced in $N = 267$ participants through an aversive film clip. To manipulate memory clarity and completeness, half of the participants viewed the original version of the film (with all sensory information clearly identifiable), while the other half viewed a version where visual and auditory blur filters obscured parts of the image and dialogue. The following day, participants were assigned to one of three conditions: ImRs with instructions to imagine and rescript the scene in as much sensory detail as possible; ImRs without such instructions; or a no-intervention control condition (NIC). On the third day, memory accuracy for the film clip was assessed using a cued recall task. Intrusive memories were assessed with a retrospective intrusion diary. Results showed no adverse effects of ImRs on memory accuracy. In fact, participants who received detailed sensory imagination instructions during ImRs exhibited greater memory accuracy compared to both those who did not receive these instructions and those in the control group, regardless of the initial clarity and completeness of the memory. No significant group differences were found in the frequency of intrusive memories.

Building on these findings, *Study III* extended the investigation to autobiographical memories. A total of 182 participants provided a detailed verbal report of an aversive life event in a free recall task. They were then randomly assigned to one of four conditions: IE, EMDR, ImRs, or NIC. One week later, participants repeated the free recall task, and independent raters evaluated changes in memory consistency, disorganization, and coherence. Involuntary memory was assessed via an app-based intrusion diary the week before and after the intervention. Additionally, psychophysiological reactivity to intrusive memories was measured during an intrusion-sampling period in both experimental sessions. None of the interventions increased contradictions or omissions in memory reports compared to NIC, suggesting that they do not impair the ability to recall specific memory details or distort their content. IE, however, was associated with more additions to memory reports, though the accuracy of these added details remains unclear. Regarding memory disorganization and coherence, the findings were mixed. IE led to improvements in structural organization by reducing disorganized thoughts, while EMDR and ImRs enhanced contextual memory coherence, reflecting improved spatial and temporal orientation of the memory. In terms of involuntary memory, all interventions reduced intrusion load. However, only ImRs reduced the number of intrusive memories relative to NIC. No group differences were observed in psychophysiological responses to intrusions.

In summary, this thesis makes an important contribution to the current literature by directly testing contrasting predictions regarding the memory effects of trauma-focused interventions. The findings challenge concerns that these interventions inherently risk distorting factual memory content, which has important implications for trauma survivors whose credibility might be questioned in legal contexts due to their treatment history. While the studies extend prior research by better modeling the complexity of memories typically addressed in clinical practice (Studies I and II) and examining autobiographical memories (Study III), their generalizability to traumatic memories and clinical populations remains limited. It is important to replicate the findings in these populations. Furthermore, the mixed results concerning intrusive memories and memory disorganization highlight the need to refine both experimental paradigms and theoretical frameworks to better account for the nuanced effects of trauma-focused interventions. Practical implications and directions for future research are discussed.

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1 General Introduction

“Funes remembered not only every leaf of every tree of every wood, but also every one of the times he had perceived or imagined it.

I suspect, however, that he was not very capable of thought. To think is to forget differences, generalize, make abstractions. In the teeming world of Funes, there were only details, almost immediate in their presence.”

Jorge Luis Borges: “Funes the Memorious”

In Jorge Luis Borges' "Funes the Memorious," the protagonist, Ireneo Funes, gains an extraordinary ability to remember every detail of his life following a head injury. However, what might initially seem like a gift, quickly reveals itself as a burden: Funes is incapable of prioritizing, abstracting, or contextualizing his experiences. Overwhelmed by a flood of vivid and overly detailed memories, he becomes paralyzed by the weight of his past and increasingly disconnected from the present, rendered incapable of action.

Borges' story illustrates the burden of involuntarily recalling past experiences with such vividness and sensory detail that they feel as though they are happening again. Although Funes' condition is fictional, it can serve as a metaphor for the experiences of individuals who suffer from intrusive and uncontrollable memories in clinical contexts. Post-traumatic stress disorder (PTSD) provides a striking example, as involuntary, sensory-rich trauma memories that are experienced with an overwhelming immediacy are one of the main diagnostic criteria of the disorder (DSM-5; APA, 2013, p. 271-272; Hackmann et al., 2004). In PTSD, these involuntary memories profoundly disrupt the daily life of those affected, reducing their sense of control (Schäfer et al., 2019) and quality of life (e.g., Olatunji et al., 2007). However, erasing such distressing memories entirely is neither a desirable nor ethical solution to address this issue. Remembering whether someone is a friend or an enemy, or recognizing whether a situation requires fear or flight, is essential for survival. In addition, a trauma survivor may be required to accurately recall the traumatic event in legal proceedings. Yet, through the lens of Borges' narrative it becomes clear that the ability to manage the uncontrollable retrieval of highly vivid and emotional memories is critical to restore everyday functioning.

In PTSD treatment, trauma-focused interventions aim to achieve precisely this: alleviating the distress caused by intrusive, involuntary traumatic memories while supporting controlled and voluntary memory recall (Brewin et al., 1996; Ehlers & Clark, 2000; Foa & Kozak, 1986). The positive effects of these interventions are well-documented. Trauma-focused treatments have been shown to reduce PTSD symptoms (e.g., Cusack et al., 2016; Schäfer et al., 2019; Watts et al., 2013) and comorbid disorders (e.g., Gros et al., 2012; National Collaborating Centre for Mental Health (UK), 2005), as well as to improve quality of life (Kaur et al., 2024). However, while their therapeutic effects are widely recognized, less attention has been given to their potential unintended effects. One growing concern is whether such interventions might not only reduce the distressing involuntary memories, but inadvertently also impair voluntary memory, particularly the factual accuracy of traumatic memories (Brewin & Andrews, 2017; Otgaar et al., 2019). This has far-reaching implications for patients, whose credibility is regularly challenged in court following trauma-focused treatment based on such concerns (Bublitz, 2020).

The following sections describe PTSD as a memory disorder and how trauma-focused interventions aim to modulate both voluntary and involuntary memory to alleviate distress. The focus lies on providing a clear understanding of both the therapeutic benefits and potential risks associated with addressing trauma memories in PTSD treatment.

1.1 PTSD as a Memory Disorder

Post-traumatic stress disorder (PTSD) is among the most prevalent mental health disorders developing in response to exposure to traumatic events (American Psychiatric Association [APA], 1994). It is hallmarked by distressing emotional memories of the traumatic event and has therefore been conceptualized as a disorder of memory (e.g., Visser et al., 2018). Memory disturbances are reflected in two core symptom clusters outlined in the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5; APA, 2013, pp. 217–272): an increase in involuntary recall of trauma-related memories and difficulties in the voluntary recall of specific event details. Prominent clinical theories emphasize the role of these memory disturbances both in the development and in the maintenance of PTSD. The following sections will explore the phenomenology of memory disturbances in PTSD, focusing on involuntary and voluntary memory impairments, as described in the DSM-5 and discuss theoretical frameworks that seek to explain these disruptions

1.1.1 Involuntary Memories in PTSD

The DSM-5 identifies the involuntary recall of trauma-related memories as a core symptom of PTSD. These manifest as persistent re-experiencing of the traumatic event through recurrent intrusive memories, flashbacks, nightmares, and increased psychological or physiological responses to internal or external trauma-related cues (e.g., Brewin, 2001; DSM-5 criteria B1-B5).

Intrusive memories are defined by their involuntary and uncontrollable nature (Brewin et al., 1996; Ehlers et al., 2004). They typically emerge spontaneously, without deliberate attempts to recall the traumatic event, and are triggered by cues associated with the traumatic event (APA, 2013, Ehlers et al., 2004). For example, a survivor of sexual assault may vividly remember the perpetrator's voice or the feeling of being tied up when exposed to cues such as the scent of a cologne similar to the perpetrator's, the sound of footsteps approaching from behind, or entering a dimly lit room similar to the place of the assault. Intrusive memories typically consist of brief sensory fragments rather than recollections of the entire event (Ehlers et al., 2002) and have been found to often capture either the moments leading up to the trauma or its most distressing moments, known as “hotspots” (Hackmann et al., 2004; Grey & Holmes, 2008). While primarily experienced as vivid mental images, intrusive memories can also include sounds, smells, or bodily sensations (Pearson et al., 2015).

Although intrusive memories of aversive autobiographical events can be observed across different forms of psychopathology (Brewin et al., 2010, Parry & O'Kearny, 2013), empirical evidence suggests that they have specific characteristics in PTSD. These include their persistent recurrence (Brewin et al., 2015; Bryant et al., 2011), heightened sensory detail (Birrer et al., 2007; Parry & O'Kearny, 2013), 'here and now' quality (Brewin et al., 2014; Ehlers et al., 2004), and the intense distress they evoke (Michael et al., 2005). These qualitative characteristics have been shown to more reliably predict the course of PTSD symptoms than both initial symptom severity (Kleim et al., 2007) and the mere presence or frequency of intrusive memories (Michael et al., 2005).

In addition to causing significant distress, intrusive memories have been shown to disrupt concentration, impair daily functioning (Holmes et al., 2017), and to be closely associated with avoidance behaviours and hyperarousal (de Vries et al., 2021). Consistent with these observations, network models of PTSD emphasize their central role and interconnectedness with other PTSD symptoms (Bryant et al., 2017; Haag et al., 2017). This supports the notion that specifically targeting a reduction of intrusive memories as a core symptom of PTSD may trigger a “therapeutic cascade” leading to broader improvements across PTSD symptoms (Iyadurai et al., 2019; McNally, 2012, p. 225).

1.1.2 Voluntary Memories in PTSD

In addition to increased involuntary memory recall, PTSD is also associated with impairments in voluntary memory retrieval. The DSM-5 includes these impairments as part of criterion D, describing the "inability to recall key features of the traumatic event" as a potential manifestation of cognitive alterations associated with PTSD.

Empirical findings suggest that voluntarily retrieved trauma memories in individuals with PTSD are often more disorganized, fragmented and incoherent compared to those of healthy individuals (Buck et al., 2007; Halligan et al., 2003; Jelinek et al., 2009; Jones et al., 2007). These characteristics have been found to be most pronounced when individuals recall the worst moments of their trauma (Jelinek et al., 2010) and to be more severe than in distressing but non-traumatic memories (Jelinek et al., 2009).

Although not all studies consistently report these patterns (e.g., Berntsen et al., 2003; Rubin et al., 2011, 2016), a recent meta-analysis by Brewin and Field (2024) suggests that variability in findings largely stem from methodological differences in how memory disorganization was assessed. Brewin and Field (2024) found that studies employing detailed coding of memory disorganization – analyzing individual utterances in trauma narratives elicited by asking participants to recount their traumatic experiences in detail, as introduced by Foa et al., (1995) – consistently reported greater disorganization in individuals with PTSD than in trauma-exposed individuals without PTSD (e.g., Halligan et al., 2003; Jelinek et al., 2009, 2010, Jones et al., 2007). In contrast, studies relying on global assessments, which evaluate the overall coherence or organization of the entire narrative through self-report or independent ratings, have yielded mixed results (e.g., Berntsen et al., 2003; Haagenars et al., 2009; Rubin et al., 2011; 2016).

Despite these inconsistencies, clinical theories consistently highlight memory disorganization as a core feature of PTSD. In addition, evidence that greater disorganization predicts higher levels of intrusive re-experiencing symptoms (Evans et al., 2007) suggests its critical role in understanding the disorder. The observed patterns of increased involuntary memory recall and impaired voluntary memory retrieval raise important questions about the underlying mechanisms driving these disruptions which will be discussed in the next section.

1.1.3 Theoretical Framework for Memory Disruptions in PTSD

Several prominent clinical theories emphasize the central role of memory disturbances in PTSD, including Emotional Processing Theory (EPT; Foa & Kozak, 1986), the Cognitive Model of PTSD (Ehlers & Clark, 2000) and Dual Representation Theory (Brewin et al., 1996; 2010). Although these models propose different mechanisms to explain the memory characteristics observed in PTSD, they converge on the notion that disruptions in the encoding, processing, and retrieval of trauma memories are fundamental to understanding the etiology and maintenance of PTSD symptoms.

For instance, EPT suggests that traumatic memories are stored in a fear structure comprising information about the feared stimulus (e.g., a gun), the individual's responses (e.g., running away, increased heart rate, fear) and the meaning of the stimulus (e.g., "I am going to die"), represented by separate nodes (Foa et al., 1989; Rauch & Foa, 2006). In PTSD, this fear structure is thought to contain an excessive number of stimulus elements, strong response elements, and unrealistic associations between neutral and danger-related stimuli, responses and meanings. These maladaptive associations cause the fear structure to be easily triggered by a high number of different stimuli, leading to intrusive memories. Maladaptive coping strategies, such as avoidance, maintain these intrusive memories by preventing the emotional processing necessary to create a more coherent fear structure which allows for more complete activation of the fear network and incorporation of more adaptive elements (Foa et al., 2006).

The Cognitive Model of PTSD (Ehlers & Clark, 2000) posits that in PTSD, the traumatic event is insufficiently integrated into its temporal and spatial context, as well as into the broader autobiographical knowledge base. This disrupted integration impairs voluntary memory retrieval and inhibitory control over involuntary trauma memories. As a result, individuals with PTSD experience poorly elaborated and poorly contextualized voluntary memories and an increased occurrence of intrusive memories triggered by similar cues.

Among these models, the Dual Representation Theory (DRT; Brewin et al., 1996; 2010) provides the most comprehensive and mechanistic framework for understanding the simultaneous occurrence of increased involuntary memories on the one hand and impaired voluntary recall on the other hand. The following sections will therefore focus on DRT as the primary theoretical foundation for discussing the dissociation between voluntary and involuntary memory in PTSD, as well as its implications for PTSD treatment.

The DRT (revised version, Brewin et al., 2010) proposes that traumatic memories are processed and stored in two separate, parallel-operating representational systems: sensation-based representations (S-Reps) and contextualized representations (C-Reps). S-Reps store detailed sensory and emotional aspects of the traumatic event and are closely linked to the physical and emotional reactions experienced during the trauma. These representations are low-level, inflexible, and cannot be deliberately retrieved. Instead, they are prone to involuntary activation by internal or external trauma-related cues. On a neurological level, S-reps are linked to the amygdala and brain regions directly involved in perception, such as the dorsal visual stream. In contrast, C-reps are abstract and more complex representations that integrate contextual and semantic information, such as the time, place and meaning of the traumatic event. These representations can be accessed both automatically and deliberately and are argued to play a critical role in supporting episodic memory retrieval and constructing coherent verbal accounts of the trauma. On a neurological level, C-Reps are associated with regions responsible for contextualization, deliberate retrieval, and reflective processing of memories, including the hippocampus, medial temporal lobe, and ventral visual stream. Their functioning is regulated by top-down processes from the prefrontal cortex (Brewin et al., 2010).

In healthy individuals, encoding of a traumatic memory involves the simultaneous formation of both S-reps and C-reps, along with associations between the two systems. This allows sensory and emotional information stored as S-reps to be retrieved together with the contextual information stored in corresponding C-reps. As a result, the memory can be effectively integrated into its semantic and autobiographical context, preventing it from being re-experienced as though it were occurring in the present. In addition, the integration of both representational systems supports increased top-down control through connections between the prefrontal cortex and the medial temporal lobe. These connections play a critical role in memory processing by providing retrieval cues, enabling the verification of retrieved information, facilitating strategies to disambiguate events with similar contextual features, and, when necessary, supporting the deliberate suppression of retrieval (Brewin et al., 2010).

In individuals with PTSD, however, extreme stress during the traumatic experience disrupts this process. Increased amygdala activation, coupled with impaired hippocampal functioning, leads to an enhanced formation of S-seps, but impairs the formation of C-reps and connections between the two systems. As a result, while individuals with PTSD may access C-reps when deliberately reflecting on or recounting the trauma, these representations are often fragmented, poorly organized and lack detail due to weak associations with the sensory information stored in S-reps. Moreover, because intrusive memories (S-reps) are experienced as overwhelmingly distressing, individuals tend to avoid engaging with them, leaving the corresponding C-reps incomplete. Conversely, S-reps remain poorly contextualized and disconnected from C-reps. This makes them highly susceptible to involuntary activation by trauma-related cues, resulting in vivid, emotionally intense intrusive memories. Thus, the behavioral and cognitive avoidance of trauma reminders further prevents the integration of S-reps and C-reps, thereby contributing to the persistence of PTSD symptoms.

1.2 Treatment of PTSD

Treatments of PTSD can be broadly categorized into trauma-focused and non-trauma-focused interventions. Trauma-focused interventions are defined as approaches that focus on the processing of the traumatic memory and/or its meaning (Bisson et al., 2007). In contrast, non-trauma-focused interventions primarily aim to support patients in developing skills for emotion regulation, managing posttraumatic symptoms, or resolving current life challenges, without directly targeting the processing of the trauma memory itself (Schäfer et al., 2019).

Given the central role of memory disruptions in PTSD, it is not surprising that trauma-focused interventions, which directly target the processing of trauma memories, have the strongest evidence base (Bisson et al., 2007; Cusack et al., 2016; Ehring et al., 2014; Lee et al., 2016; Watts et al., 2013) and are recommended as the first-line treatment in international treatment guidelines (APA, 2017; Bisson et al., 2019; National Institute for Health and Care Excellence, 2018; Phelps et al., 2022; Schäfer et al., 2019). Trauma-focused interventions include trauma-focused cognitive behavioral therapy (TF-CBT), which typically incorporates prolonged imaginal exposure (IE) to the trauma memory (Foa & Rothbaum., 1998). Additionally, Eye Movement Desensitization and Reprocessing (EMDR, Shapiro, 1989; 2018) is recommended by treatment guidelines as an alternative trauma-focused approach. Furthermore, accumulating empirical evidence supports the efficacy of Imagery Rescripting (ImRs; Arntz & Weertman, 1999; Smucker et al., 1995) as a trauma-focused intervention, though it has not yet been incorporated into official guidelines (Boterhoven Haan et al., 2020; Morina et al., 2017). The following sections will first describe the intervention protocols of IE, EMDR, and ImRs in more detail, followed by a discussion of their proposed underlying mechanisms, as well as their intended and potential unintended effects on memory in PTSD.

1.2.1 Imaginal Exposure

Imaginal Exposure, developed by Foa and colleagues (Foa & Rothbaum., 1998), is the most extensively researched trauma-focused intervention and a core component of trauma-focused cognitive behavioral therapy (TF-CBT) for PTSD (APA, 2013; Powers et al., 2013). In IE, patients repeatedly relive their traumatic memory in their imagination until the distress associated with the memory declines. During the first sessions, the memory is revisited chronologically, from beginning to end. In later sessions, the focus may shift on the most emotionally distressing moments or “hotspots” of the memory (Foa et al., 2007). Patients are encouraged to imagine their memory as vividly and in as much detail as possible, engaging all sensory modalities and focusing on all aspects of the trauma, including their emotions, thoughts and bodily sensations they experienced during the traumatic event. To support the imagination process, patients are asked to imagine and verbalize aloud what they are experiencing from the first-person perspective and in the present tense, “as if it were happening now”. Sessions are audio-recorded, and as part of their homework, patients are required to listen to these recordings daily.

1.2.2 Eye Movement Desensitization and Reprocessing

The EMDR treatment protocol was first introduced by Francine Shapiro in 1989. While it initially faced skepticism (e.g., Herbert et al., 2000), it has since gained widespread recognition as a trauma-focused intervention. Today, EMDR is endorsed as an effective treatment for trauma-related disorders by multiple international clinical guidelines (e.g., APA, 2017; Phelps et al., 2022; Schäfer et al., 2019). The protocol consists of eight structured phases (Shapiro, 2001; 2018). The first two phases focus on establishing treatment goals, building a stable therapeutic relationship, and preparing the patient for treatment. Phases three through seven involve the actual processing of the trauma memory:

In phase three, the target memory for the particular session is identified. Here, the patient is asked to identify the most distressing and salient image, along with the negative, maladaptive cognitions, emotions and bodily sensations associated with the traumatic memory. In addition, a positive target cognition is defined as a more adaptive and less distressing alternative to the negative cognition. During the desensitization phase (phase four), the patient is asked to keep the image associated with the traumatic memory in mind and to simultaneously perform horizontal eye-movements, typically following the therapist’s finger moving horizontally (although other forms of bi-lateral stimulation such as tapping or listening to alternating beeps are also possible, e.g., De Jongh et al., 2013; Lee & Cuijpers, 2013). During this phase, the patient is encouraged to follow spontaneous associations of traumatic images, thoughts, emotions and bodily sensations that come up, and the process is repeated until the distress declines. In phase five, the installation phase, the aim is to strengthen the positive target cognition by asking the patient to focus on the positive cognition and to perform slower eye movements. Phase six involves a body scan, where the patient is asked to identify any lingering somatic tension or distress related to the memory which are then processed through further bilateral stimulation. Finally, phases seven and eight focus on affective stabilization of the patient, debriefing, and evaluation of the treatment effects.

1.2.3 Imagery Rescripting

Although Imagery Rescripting (ImRs) has roots tracing back to the late 19th century (Janet, 1919, Van Der Kolk & Van der Hart, 1989), the first structured ImRs protocols for the treatment of traumatic memories only emerged in the late 20th century, developed by Smucker and colleagues (Smucker et al., 1995; Rusch et al., 2000) and by Arntz and Weertman (1999, 2007). While initially developed for the treatment of childhood trauma, ImRs is now widely used for PTSD (Morina et al., 2017; Kip et al., 2023) and other psychological disorders (e.g., Hyett & McEvoy, 2020).

Although there are some variations among protocols, both Smucker et al.'s and Arntz et al.'s protocols share the same core principles and follow a similar procedure: In the first step, the traumatic memory is re-activated in the imagination, either entirely (Smucker et al., 1995) or only up to the hotspot (Arntz & Weertman, 1999). This involves engaging all sensory modalities (i.e., what the person is seeing, hearing, feeling), associated thoughts, emotions, and physical sensations. Patients are instructed to imagine what was happening with their eyes closed, from a first-person perspective, and in the present tense, while describing aloud their experience. In the next step, the course of events is changed in the patient's imagination to reduce distress associated with the memory and to ensure that their needs are met. In the original protocols designed for the treatment of childhood trauma memories, this takes place in several phases. First, the patients imagine their adult self or another helping figure intervening in the scene (e.g., disempowering the perpetrator). Then, the patient imagines receiving support from the adult from the child's perspective (Arntz & Weertman, 1999) or imagines taking care of the child from the adult's perspective (Smucker et al., 1995). As in the memory reactivation phase, patients are encouraged to imagine the new course of events as vividly and detailed as possible as this is considered necessary for therapeutic progress. Typically, the sessions are audio-recorded, and patients are instructed to listen to the recording at home as part of their homework (Arntz & Weertman, 1999; Smucker et al., 1995).

Arntz’s protocol further distinguishes between two variations during the rescripting phase: In variant A (patient-led rescripting), the patient imagines entering the traumatic scene as their adult self and decides how to intervene to change the course of events in a desired direction. In variant B (therapist-led rescripting), the therapist enters the scene in the patient’s imagination, confronting and disempowering the perpetrator and addressing the child’s needs. Arntz and colleagues recommend incorporating both variations throughout treatment to maximize their respective benefits. Variant B is typically introduced early in treatment to provide the patient with a sense of safety and support. As the treatment progresses, transitioning to Variant A can help enhance the patient’s self-efficacy by encouraging them to develop their own coping images (Arntz et al., 2014).

In summary, all three trauma-focused approaches described above involve the imaginative reactivation of the traumatic event, either partially or in its entirety. In IE, the entire traumatic experience is vividly relived and described in detail, whereas in ImRs, the memory is actively changed in the imagination to reduce distress and address the patient’s unmet needs. In EMDR, specific parts of the memory are reactivated during phase three, while the desensitization phase takes a less structured approach, allowing for a spontaneous associative process which can focus on traumatic images, thoughts, emotions, and/or bodily sensations.

1.3 Intended Memory Effects of Trauma-Focused Interventions

Although traumatic memories are associated with significant distress, the primary aim of IE, EMDR, and ImRs is not to erase these memories entirely. Instead, these interventions aim to reduce the uncontrolled and involuntary recall of trauma memories and to alleviate the emotional distress associated with their voluntary recall, but to preserve or even enhance the ability to retrieve the traumatic memories voluntarily.

1.3.1 Proposed Working Mechanisms of Trauma-Focused Interventions

As previously outlined, the Dual Representation Theory (DRT) posits that increased intrusive memories and impaired voluntary memory observed in PTSD result from a disconnection between sensory-bound memory representations (S-reps) and contextual memory representations (C-reps). According to this model, these memory disturbances persist because individuals with PTSD engage in cognitive and behavioral avoidance of their traumatic memories, which prevents the successful integration of these representations. It is argued that trauma-focused psychological interventions work by facilitating the integration of these dissociated memory representations. This, in turn, improves the inhibition of involuntary recall (e.g., intrusive memories) while at the same time improving voluntary recall. Within this framework, IE, EMDR, and ImRs are thought to achieve this integration through similar mechanisms (Brewin et al., 2010):

Imaginal Exposure is proposed to facilitate this integration by encouraging patients to engage with their traumatic memories in detail, repeatedly revisiting the scene in their imagination and providing a vivid, elaborated narrative of the traumatic event. This process is thought to systematically trigger the retrieval of S-reps, holding them in focal attention long enough to enable their transfer into more elaborated and contextualized C-reps. This, in turn, is believed to aid in embedding the memory representations within the autobiographical memory system, supporting their contextualization. Additionally, IE is thought to strengthen the connections between S-reps and C-reps, resulting in more elaborated and coherent voluntary memories (C-reps) and enhanced inhibitory control over intrusive memories (S-reps).

EMDR is proposed to similarly foster memory contextualization through its exposure elements (i.e., encouraging the patient to recall the memory together with the most salient images, emotions, thoughts and bodily sensations). Additionally, the simultaneous tasks of recalling the memory and performing eye movements have been found to compete for limited working memory resources, thereby reducing the vividness and emotional intensity of the memories under attentional focus (Brewin et al., 2010; van den Hout & Engelhard, 2012; van den Hout et al., 2012). Within the framework of DRT, the reduction in emotional intensity is seen as an alternative way to facilitate the elaboration of C-reps and strengthen the connections between S-reps and C-reps. Furthermore, DRT posits that EMDR introduces additional contextual cues, such as the therapist's hand movements, which associate the new memory representations with the safe present rather than the dangerous past.

With regard to ImRs, DRT proposes that the C-rep associated with the traumatic event is first reactivated, which subsequently activates associated S-reps. This process allows all relevant S-reps to be connected to a new, more elaborated C-rep, thereby contextualizing them. Through the introduction of new, positive coping images in the rescripting phase, the C-rep can be further updated with positive elements. This is proposed to lead to an increased spontaneous activation of more positive emotions from S-reps (Brewin et al., 2010).

To summarize, according to DRT, interventions such as IE, EMDR, and ImRs facilitate the integration of dissociated memory representations, leading to more elaborated and contextualized representations of the traumatic event. This integration reduces the salience and uncontrolled activation of distressing involuntary memories (S-reps). Furthermore, the voluntary memory (C-reps) becomes more elaborated, as information about the traumatic event becomes more accessible through voluntary recall (Brewin et al., 2010). Inherently, this should lead to more organized and coherent voluntary memory recall. Note that this view aligns with other clinical theories, such as the Cognitive Model of PTSD (Ehlers & Clark, 2000) and the Emotional Processing Theory (Foa et al., 1989; 2006) mentioned earlier, which similarly predict that successful PTSD treatment reduces intrusive memories and improves voluntary memory. Specifically, these models propose that trauma-focused interventions facilitate the elaboration and integration of the trauma memory into the broader autobiographical context (Ehlers & Clark, 2000) or into a more coherent fear structure (Foa et al., 2006). This is believed to both improve inhibitory control over intrusive memories and to enhance voluntary recall, resulting in less fragmented or more coherent voluntary memories.

Different explanations have been proposed to account for how exactly trauma-focused interventions bring about these changes in trauma memories. On the one hand, it has been suggested that these interventions form new memory representations which coexist with the original memory representations (Brewin et al., 2006). On the other hand, it has been proposed that they may directly modify the original memory representations (e.g., Arntz, 2012; Dibbets et al., 2011; Kunze et al., 2019; van den Hout & Engelhard, 2012).

The retrieval competition account (Brewin, 2006) posits that trauma-focused interventions do not directly alter the original memory representations but instead facilitate the formation of new, more elaborated, and less negatively valenced representations. These new representations compete with the original disintegrated and negatively valenced memories when the same retrieval cues are encountered. Several factors have been proposed to contribute to the retrieval advantage of these new memory representations (Brewin, 2006): Rehearsal, particularly elaborative rehearsal involving semantic processing of memory content, increases their activation and accessibility. The therapeutic context enhances their distinctiveness by encouraging deliberate self-exposure to trauma-related material. Moreover, a reduction in anxiety during treatment adds a more positive emotional valence to these new representations, further increasing the likelihood of their retrieval. In line with this view, the Dual Representation Theory posits that IE, EMDR, and ImRs promote the formation of new, more elaborated contextual representations (C-reps) and less negatively valenced sensory-bound representations (S-reps). Following successful intervention, these newly integrated representations are expected to effectively compete with the original C-reps and S-reps when trauma reminders are encountered (Brewin et al, 2010). Empirical evidence supports this mechanism, particularly in exposure-based treatments, where a new inhibitory memory is created while the original memory remains intact (inhibitory learning; Craske et al., 2014).

In addition to forming new memory traces, it has been suggested that trauma-focused interventions, specifically ImRs and EMDR, may also directly modify the original trauma memory representations by changing their meaning, emotional valence and intensity (e.g., Arntz, 2012; Dibbets et al., 2011; Kunze et al., 2019; van den Hout & Engelhard, 2012). This assumption is supported by research demonstrating that memories, once consolidated, are not permanently stable but can become destabilized upon retrieval. In this labile state, memories can be strengthened, weakened, or modified by corrective information before being reconsolidated (Nader et al., 2000). Experimental studies indicate that both pharmacological agents (e.g., Kindt & Soeter, 2018; Sevenster et al., 2013) and behavioral tasks (e.g., Golkar et al., 2017; James et al., 2015) presented after memory reactivation can disrupt reconsolidation. Notably, these interventions selectively reduced the aversive emotions associated with the targeted memories, but left knowledge of factual memory details intact. It has been suggested that ImRs and EMDR may work in a similar way, directly altering the meaning, emotional valence, and intensity of the original memory, but leaving factual knowledge of the event intact (e.g., Arntz, 2012; van den Hout & Engelhard, 2012). Although there is some preliminary evidence in favour of this assumption (e.g., Dibbets et al., 2012), more research is needed to better understand the underlying memory mechanisms of these interventions.

To summarize, the precise mechanisms by which EMDR and ImRs exert their effects – whether by creating new memory traces similar to IE or by directly modifying existing ones – remain unclear. However, both ideas can be reconciled with the predictions of the DRT regarding the effects of trauma-focused interventions on voluntary and involuntary memory retrieval. According to DRT, interventions such as IE, EMDR and ImRs support the integration of dissociated memory representations. Regardless of whether these new associations are reconsolidated into the original memory trace or encoded as part of a newly formed memory representation, the outcome should be the same (although reconsolidation may offer the advantage of longer lasting treatment effects, see Kindt & Elsey, 2023): involuntary, intrusive memories should be reduced, and voluntary memory retrieval should be improved.

1.3.2 Empirical Evidence for Effects on Involuntary Memory

Empirical evidence supports the assumptions of Dual Representation Theory regarding the effects of trauma-focused interventions on the reduction of involuntary intrusive memories. The efficacy of IE, EMDR, and ImRs in reducing the frequency, distress, and vividness of intrusive memories has been demonstrated in a number of both laboratory analogue studies with healthy participants (e.g., Strohm et al., 2019; Xu et al., 2023) and clinical studies (e.g., Brewin et al., 2009; Speckens et al., 2006). These findings are supported by evidence from several meta-analyses which consistently demonstrate the efficacy of TF-CBT, including IE, and EMDR in alleviating PTSD symptoms (e.g., Bisson et al., 2007; Cusack et al., 2016; Ehring et al., 2014; Watts et al., 2013; Wright et al., 2024; Yunitri et al., 2023). Compared to IE and EMDR, the evidence base for ImRs is more limited, with only two meta-analyses conducted to date (Kip et al., 2023; Morina et al., 2017). Nevertheless, the results are promising as both meta-analyses found ImRs to be more effective than passive control conditions and comparable to IE and EMDR in reducing PTSD symptoms.

1.3.3 Empirical Evidence for Effects on Voluntary Memory

Empirical evidence regarding the assumptions of Dual Representation Theory on the effects of trauma-focused interventions on voluntary memory improvement is more mixed. While some studies have reported improvements in memory organization following IE (e.g., Foa et al., 1995; Van Minnen et al., 2002), others have failed to replicate these findings (e.g., Bedard-Gilligan et al., 2017). Moreover, evidence supporting memory reorganization as a central mechanism of action in IE remains limited (e.g., Cooper et al., 2017; Van Minnen et al., 2002). For EMDR and ImRs, Dual Representation Theory suggets that reductions in emotionality, intensity, and vividness of voluntary memories should facilitate voluntary access to memory representations and enhance memory organization and coherence (Brewin et al., 2010). However, it remains unclear whether these changes actually result in such improvements (Arntz et al., 2007; Meckling et al., 2024). For instance, Maxfield et al. (2008) observed that EMDR reduced subjective "thought clarity," which may indicate a reduction in memory organization. However, more recent research found no evidence that reductions in vividness following EMDR were accompanied by changes in memory coherence or fragmentation (Meckling et al., 2024). Similarly, the only study to date examining the impact of ImRs on memory organization reported no effect (Kindt et al., 2007).

In summary, while trauma-focused interventions such as IE, EMDR, and ImRs have been found to effectively reduce involuntary memories, it remains unclear to what extent these interventions improve memory organization and coherence as predicted by clinical theories.

1.4 Unintended Effects of Trauma-Focused Interventions on Voluntary Memory

As previously noted, trauma-focused interventions aim to reduce the frequency and intensity of intrusive memories, but to preserve or even enhance the deliberate recall of trauma memories. Nevertheless, experts in legal psychology have expressed concerns regarding potential unintended intervention effects on voluntary memory. Specifically, it has been suggested that these interventions may compromise the *factual accuracy* of voluntarily recalled trauma memories (e.g., Otgaar et al., 2021). These concerns date back to the so called “memory wars” which arose in the late 20th century when individuals reported to recall allegedly repressed memories of childhood sexual abuse after undergoing so called “recovered memory therapy” (see Lynn et al., 2023 for a review). As many of these “recovered” memories included implausible or outright impossible events (Loftus, 1997; McNally, 2003), doubts were raised about the authenticity of memories reported after these treatments. Critics, including experts from legal and cognitive psychology, emphasized scientific evidence indicating that traumatic events are rarely forgotten (see Lynn et al., 2023) and argued that suggestive techniques used in “recovered memory therapies”, such as hypnosis or guided imagery, pose a risk of creating false memories (Otgaar et al., 2018). This concern was substantiated by numerous cases where former clients of therapists employing recovered-memory techniques later retracted their allegations of childhood abuse and pursued legal actions against their therapists, stating that their memories where the product of suggestion (Lynn, 2023). This triggered an influential line of experimental research systematically investigating how false memories are formed, which will be presented in more detail in the following section.

1.4.1 Experimental Paradigms Demonstrating Memory Fallibility

Different experimental paradigms have been employed to investigate under what circumstances false memories are formed (Loftus, 2005; Loftus & Klemfuss, 2023). Among the most commonly employed methods for studying suggestion-induced false memories are the misinformation paradigm, memory implantation paradigm, false feedback paradigm, and imagination inflation paradigm (for a comprehensive overview of methodologies in false memory research, see Otgaar et al., 2018).

The misinformation paradigm was developed to demonstrate how exposure to counterfactual information after an event can distort or alter a person's memory of the original event (Loftus et al., 1978). Studies on this effect typically follow a three-phase procedure: In the first phase, a memory is experimentally induced by presenting participants with stimuli such as photographs (e.g., Stark et al., 2010) or videos (e.g., Sutherland & Hayne, 2001) or by involving participants in a staged event (e.g., Otgaar et al., 2010). In the second phase, misleading information is introduced, often through post-event narratives presented as authentic accounts of the event (e.g., Stark et al., 2010) or through suggestive questions (e.g., asking participants who viewed a video of a car accident about a yield sign when the video actually showed a stop sign; Loftus, 1997). Finally, in the third phase, participants' memory of the original event or stimulus is tested. Studies using this paradigm consistently showed that a significant minority of participants incorporated the misleading information into their recollection of the original event, causing the so called *"misinformation effect*" (Loftus et al., 1978). Research further shows that this effect increases as the time delay between the witnessed event and exposure to misinformation increases (Loftus et al., 1978). However, it has been shown that the misinformation effect can also be reduced if participants are warned that they may encounter misleading information (e.g., Blank & Launay, 2014; Karanian et al., 2020).

In addition, it has been shown that it is not only possible to alter memories of event details but also to implant rich autobiographical memories of entire events that never actually took place. This effect has been demonstrated using the memory implantation paradigm which typically employed the following procedure (Loftus & Pickrell, 1995): Participants are presented with a list of events from their childhood, some of which actually took place and some of which did not, as confirmed by family members contacted by the experimenter. They are then asked to recall these events as accurately as possible during multiple interviews. To enhance the plausibility of the fabricated events and increase the participants' belief that the events actually took place, suggestive questioning is employed, along with the presentation of false statements from informed family members and/or doctored photographs that supposedly depict the participants at the fabricated event. Again, studies employing the memory implantation paradigm showed that a substantial number of participants developed false memories of the fabricated event (see Scoboria et al., 2017 for a review).

The imagination inflation paradigm has demonstrated that imagining events is particularly effective in implanting false memories as well as altering factual details of existing memories. These studies typically follow a three-stage procedure. First, participants are presented with a list of life events and asked to rate their confidence that these events occurred. In a subsequent session, participants are instructed to imagine some of these events and then re-rate their confidence in the events on the list. Findings consistently show that imagining an event increases participants' confidence that the event occurred, even when their initial confidence was low (e.g., Garry et al., 1996; Horselenberg et al., 2000). Similarly, research has found that imagination can enhance confidence in having performed certain actions, even when those actions were only imagined (e.g., Li et al., 2020; Thomas et al., 2003). Beyond creating false memories for events that never occurred (e.g., Mazzoni & Memon, 2003), imagination has also been shown to distort existing memories, such as memories of objects that were actually seen (Lyle & Johnson, 2007) or events that were genuinely experienced (Goff & Roediger, 1998). Note that more recent findings indicate that imagination may more commonly lead to false *beliefs* rather than false *memories*. These false beliefs involve a sense of confidence in the occurrence of an event but lack the vivid recollection typically associated with false memories (Smeets et al., 2009).

In addition to suggestion-induced false memories or false beliefs, it has been shown that false memories can also occur spontaneously, without external suggestive pressure. This phenomenon has mainly been demonstrated using the Deese/Roediger-McDermott (DRM) paradigm (Deese, 1959; Roediger & McDermott, 1995). In this paradigm, participants are presented with a list of words that are semantically related (e.g., bed, rest, tired, dream, snooze, blanket) and associated with a non-presented word, referred to as the "critical lure" (e.g., sleep). When participants are later asked to recall or recognize the words from the list, studies consistently found that participants often falsely recall or recognize the critical lure, mistakenly believing it was part of the original list (e.g., Cann et al., 2011; Roediger & McDermott, 1995).

1.4.2 Theoretical explanations for memory distortions

The Discrepancy Detection Principle (Tousignant et al., 1986) and the Source Monitoring Framework (Johnson et al., 1993; Lindsay & Lohan, 2000) provide explanations for the memory errors observed in these studies. The Discrepancy Detection Principle posits that accurate memory relies on the ability to detect discrepancies between what was actually experienced and post-event information. Accordingly, memory errors are more likely when discrepancies go unnoticed, particularly when misinformation is subtle, the original memory is weak, or warnings about misinformation are absent (e.g., Brewin & Andrews, 2017; Leding & Antonio, 2019; Loftus, 1992).

The Source Monitoring Framework (Johnson et al., 1993; Lindsay & Johnson, 2000) explains memory errors as failures in accurately attributing memories to their original sources, such as whether a memory originates from personal experience, imagination, or external sources like conversations, or media. Source monitoring relies on evaluating various aspects of the memory, including sensory details, contextual information, and cognitive processes associated with a memory, to determine its origin. The accuracy of these judgements depends on the quality and quantity of these features. For example, inattentive encoding or distractions during encoding may result in fewer distinguishing features being stored, making it harder to differentiate between perceived and imagined sources. Additionally, suggestive questions or misleading information can increase the risk of source confusions. Furthermore, when an event feels familiar but the source cannot be identified, individuals may mistakenly attribute it to personal experience, resulting in a false memory. The likelihood of false memories increases when imagined and real events share perceptual or conceptual similarity (Lyle & Johnson, 2007; Thomas et al., 2003). For example, highly vivid or plausible imagined scenarios are more likely to be misattributed to actual experience (e.g., Scoboria et al., 2004).

1.4.3 Implications of False Memory Research for Clinical Practice

Having outlined the experimental paradigms demonstrating the fallibility of memory and the theoretical explanations for these phenomena, the following section explores how this research informs our understanding of potential memory distortions in trauma-focused clinical interventions.

1.4.3.1 Comparing False Memory Paradigms and Clinical Interventions: Parallels and differences

The paradigms used in false memory research to demonstrate memory fallibility share notable procedural similarities with trauma-focused interventions such as IE, EMDR, and ImR which has led to concerns that these interventions might similarly increase the risk for false memories (e.g., Otgaar et al., 2021). For instance, all these interventions involve imagination as a core component. In addition, ImRs involves the explicit modification of memory contents in the imagination, which could be compared to the imagination of misinformation in false memory studies. Critically, in ImRs, patients are encouraged to imagine these modifications as vividly as possible, with a high level of sensory detail and emotional engagement (Arntz, 2012) – factors that have been shown to impair accurate source monitoring (Johnson & Raye, 1981). Furthermore, EMDR has been shown to reduce the emotional intensity and vividness of memories targeted during treatment (van den Hout & Engelhard, 2012). Given that weaker memories, such as those that have faded over time, are more vulnerable to distortion (Loftus et al., 1978), this reduction in vividness could similarly impair an individual's ability to detect discrepancies when exposed to counterfactual information. Additionally, reduced memory vividness may encourage reliance on the general meaning or gist of events rather than precise, item-specific details when recalling the memory, which has been linked to an increased likelihood of false memories, even in the absence of external suggestive pressure (Brainerd & Reyna, 2002; Houben et al., 2020). Furthermore, all three interventions involve memory reactivation, which, under certain conditions, can render memories temporarily unstable and susceptible to modification (Nader et al., 2000). Against this background, imagination-based interventions – particularly ImRs, which involves explicit instructions to deliberately modify memory content, and EMDR, which reduces memory vividness – have recently drawn attention for their potential not only to reduce involuntary memories but also to inadvertently distort factual details of voluntary memories (Otgaar et al., 2021).

However, despite these similarities, there are also significant methodological and procedural differences between false memory paradigms and trauma-focused interventions, raising the question of whether findings from the false memory literature can be generalized to clinical interventions. Notably, false memory studies typically employ suggestive techniques that do not align with clinical best practice. For instance, most false memory paradigms introduce misinformation through external sources, such as false statements from informed family members, fabricated evidence like doctored photographs, or suggestive questions that subtly incorporate misinformation. In contrast, evidence-based trauma-focused interventions avoid using such suggestive methods. In ImRs, where counterfactual information is introduced, patients are transparently informed about the intentional use of counterfactual imagery as part of the therapeutic process. Given empirical evidence that warnings about misinformation can reduce susceptibility to false memories (Karanian et al., 2020; Oeberst et al., 2021), this transparent approach may similarly have a protective effect. In addition, the cognitive process of intentionally altering a memory by creating positive coping images in the imagination provides critical memory source information, aiding in the distinction between what was experienced and what was merely imagined (e.g., Foley et al., 2006; Henkel & Carbuto, 2008). Furthermore, false memory studies, particularly imagination inflation studies, often assess participants' *confidenc*e in the occurrence of suggested events rather than the actual *accuracy* of their memories. This is a critical distinction, as confidence in a memory does not reliably reflect its factual accuracy (Odinot et al., 2013). Another important difference lies in the nature of the memories under investigation. False memory research typically investigates the effects on simple, recently induced memories of photographs, word lists, or videos, often before these memories have undergone consolidation. In contrast, trauma-focused interventions work with autobiographical memories, which are personally relevant and emotionally charged. Such memories tend to be better retained than neutral or irrelevant ones (e.g., Anderson et al., 2006), making them less susceptible to distortion.

In summary, although procedural similarities between false memory paradigms and trauma-focused interventions have raised concerns about potential memory distortions, it remains unclear whether findings from false memory studies can be directly generalized to trauma-focused as applied in clinical practice.

1.4.3.2 Evidence on Memory Distortions Induced by Clinical Interventions

There is only very limited systematic research into the effects of IE, EMDR, and ImRs on the accuracy of voluntary memories. Most previous studies followed a similar procedure: a memory was experimentally induced in a healthy sample, using different types of stimulus material, followed by an intervention or no intervention and then, memory accuracy was assessed using free recall, memory recognition or cued recall tasks.

For IE and ImRs, most studies used the trauma film paradigm, where aversive memories were induced with film clips depicting distressing events, such as real-life footage of traffic accidents (Hagenaars & Arntz, 2012) or rape scenes (Ganslmeier et al., 2023; Siegesleitner et al., 2019). These films reliably elicit negative emotional reactions, high levels of distress, and intrusive memories (James et al., 2016). One study sought to increase the personal relevance of the induced memories by using the Trier Social Stress Test (TSST; Kirschbaum et al., 1993), a standardized social stressor, for memory induction. Across these studies, no negative effects of IE or ImRs on memory accuracy were found, regardless of the stimulus material or the method used to assess memory. Some studies even found improved memory accuracy for IE as assessed in a free recall task (Ganslmeier et al., 2023) and for ImRs as assessed in both memory recognition or cued recall tasks (Ganslmeier et al., 2022; Hagenaars & Arntz, 2012).

In contrast, studies on the effects of EMDR have produced more mixed results. These studies assessed the effects of eye movements performed during memory recall as an experimental analogue for EMDR. While some of these studies used film clips of traffic accidents (e.g., Calvillo & Emami, 2019; Houben et al., 2018), most studies relied on simpler stimuli such as word lists (e.g., Houben et al., 2020), or pictures (e.g., Leer et al., 2017; Leer & Engelhard, 2020) for memory induction. Importantly, these studies often incorporated an additional element not present in studies of IE and ImRs: after the intervention, participants were presented with misinformation embedded in post-event narratives, and their memory for the original stimulus was subsequently tested (e.g., Calvillo & Emami, 2019; Houben et al., 2018; van Schie & Leer, 2019). Findings from these studies suggest that eye movements during memory recall can increase susceptibility to misinformation, leading participants to falsely remember misinformation as part of the original event (Houben et al., 2018). However, these results have not been consistently replicated (Calvillo & Emami, 2019; van Schie & Leer, 2019). Additionally, some studies using stimulus discrimination tasks found that eye movements reduced discrimination speed, but did not impair discrimination accuracy (Leer et al., 2017; van den Hout et al., 2013). Only two studies, to our knowledge, examined the effects of eye movements on memory accuracy in the absence of external suggestive pressure (i.e., without presenting misinformation). One of these studies found that eye movements increased the risk of spontaneous false memories for word lists, using the Deese/Roediger-McDermott paradigm (Houben et al., 2020). The other study investigated changes in the content of distressing autobiographical memories and found no differences between participants who performed eye movements during memory recall and those who engaged in recall only (Meckling et al., 2024).

Several limitations restrict the generalizability of prior research on the effects of IE, EMDR, and ImRs on memory accuracy. Although some studies have attempted to increase the complexity of the memories under investigation (Ganslmeier et al., 2022; Meckling et al., 2024), most evidence comes from studies using simple stimuli such as word lists, pictures, or short film clips for memory induction. These experimentally induced memories lack the complexity, emotional salience, and personal relevance of autobiographical memories, limiting the applicability of findings to clinical contexts. Additionally, many studies delivered the intervention immediately after memory induction, before memory consolidation could occur (Hagenaars & Arntz, 2012; Houben et al., 2018, 2020). In clinical practice, however, interventions typically target memories that have already undergone consolidation, highlighting the timing of the experimental interventions as a significant limitation. Evidence on the effects of EMDR is further complicated by the use of the misinformation paradigm, which introduces conditions that do not align with best clinical practices. In addition, these studies often assessed the effects of isolated eye movements rather than the full intervention protocol (e.g., Calvillo & Emami, 2019; Houben et al., 2018; Leer & Engelhard, 2020). This reductionist approach may overlook important factors that may impact the memory effects of EMDR in clinical practice.

In summary, previous studies indicate that IE and ImRs do not lead to memory distortion and may even enhance memory accuracy in some contexts. Findings for EMDR are more inconsistent, with some evidence suggesting increased susceptibility to misinformation or spontaneous false memories, while other studies fail to replicate these results. Nonetheless, the methodological limitations of prior studies emphasize the need for further research into the effects of these interventions that more closely models the conditions in which these interventions are applied in clinical practice.

1.5 Aims of the Thesis

The aim of this thesis is to investigate the differential effects of trauma-focused interventions – namely EMDR, IE, and ImRs – on the voluntary and involuntary retrieval of distressing emotional memories. While the effectiveness of these interventions in alleviating PTSD symptoms, including intrusive memories, is well documented, their effects on voluntary memory remain largely unknown. Clinical theories suggest that trauma-focused interventions should improve voluntary memory, particularly in terms of memory coherence and organization. In contrast, concerns raised in the field of legal psychology suggest that these interventions might impair voluntary memory, particularly in terms of accuracy. Although such concerns have far-reaching consequences for those affected, particularly with regard to the assessment of their credibility in legal proceedings, systematic research on the effects of these interventions on voluntary memory retrieval is scarce.

Investigating the effects of trauma-focused interventions on memory poses inherent challenges, particularly when dealing with autobiographical memories. Since the content of such memories cannot be experimentally controlled, assessing memory accuracy directly is not feasible. Analogue paradigms, which enable the controlled induction of memories, provide a valuable method to investigate potential negative effects of trauma-focused interventions on memory accuracy systematically. Although previous studies have employed such paradigms, they have often overlooked critical factors specific to the clinical application of these interventions. For instance, the types of memories typically targeted in treatment and the therapeutic instructions provided during treatment can strongly influence memory outcomes. Failing to account for these factors limits the ecological validity and generalizability of existing findings. Additionally, little attention has been given to whether these interventions improve the quality of voluntary memory, as predicted by clinical theories, further highlighting the need to systematically investigate their effects on voluntary memory. This thesis aims to address some of these limitations by systematically investigating whether EMDR, IE, and ImRs can effectively reduce involuntary memories and the associated distress, while preserving the accuracy and quality of voluntary memory. To this end, three experimental analogue studies examining intervention effects on both voluntary and involuntary memory were conducted and will be presented in this thesis.

Study 1 and 2 assessed the effects of these interventions on experimentally induced aversive memories. This approach provided the level of experimental control over memory content required to assess their effects on memory accuracy. Unlike earlier research, which often relied on overly reductionist intervention protocols, simplistic stimuli for memory induction, or focused on memories that had not yet undergone consolidation, Studies 1 and 2 sought to better account for the conditions under which these interventions are delivered in clinical practice by modelling them experimentally. **Study 1** examined the effects of EMDR, ImRs, and IE on memory accuracy. An adapted version of the Trier Social Stress Test was employed to induce a distressing memory in a healthy, but socially anxious sample. Memory induction, intervention and memory test took place on three separate days, thereby allowing to assess the effects on consolidated memories. By investigating the effects on personally more meaningful, complex memories that had already undergone consolidation, study 1 extends previous research in important aspects. **Study 2** focused on the effects of ImRs, investigating whether it might impair factual memory content under certain risk conditions by experimentally modelling clinical scenarios that could increase the likelihood of such impairments. Specifically, it aimed to more closely model the quality of memories typically addressed in treatment, as well as the therapeutic instructions commonly used, which might impair source monitoring and discrepancy detection – factors that have been largely overlooked in previous studies.

Building on the controlled assessment of memory accuracy in Studies 1 and 2, **Study 3** aimed to further enhance external validity by assessing the effects of IE, EMDR and ImRs on distressing autobiographical memories. Since the accuracy of autobiographical memories cannot be directly verified, the study used memory consistency as a proxy for memory validity, aligning with practices commonly employed in legal settings to evaluate the reliability of testimony statements. In addition to evaluating memory consistency, Study 3 expanded upon previous research by investigating intervention effects on memory coherence and disorganization. This approach allowed us to simultaneously test predictions from legal psychology concerning the interventions' impact on factual memory content, while also evaluating clinical theories that anticipate improvements in voluntary memory retrieval and reductions in intrusive memories.

2 Study I

Does Treating Emotional Memories Come at a Price? Comparing the Effects of Imagery Rescripting, Eye Movement Desensitization and Reprocessing and Imaginal Exposure on Memory Accuracy

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The study was pre-registered (https://osf.io/7sveq). Data, R-Code and materials have been made available online (https://osf.io/mwbtc/).

Abstract

Eye Movement Desensitization and Reprocessing (EMDR), Imaginal Exposure (IE), and Imagery Rescripting (ImRs) are trauma-focused interventions aimed at reducing trauma-associated psychopathology. Despite their clinical effectiveness, concerns remain about the potential impact of these interventions on the accuracy of memories addressed in treatment. This study therefore examined the effects of EMDR, IE and ImRs on memory accuracy. Two hundred sixty-five healthy participants underwent the Trier Social Stress Test and received one of the three interventions or no intervention (NIC) on the following day. Memory accuracy was assessed one week later using a cued recall task. Contrary to expectations, the interventions showed no differences in their effects on memory accuracy; thus, the three interventions led to neither an improvement nor an impairment in memory compared to NIC. This aligns with recent findings indicating that ImRs and IE do not distort memory. Although there are studies suggesting that EMDR impairs memory accuracy, this could not be confirmed in our study. The findings challenge the notion that trauma-focused psychological treatments such as EMDR, ImRs, and IE cause memory alterations, which is particularly reassuring in legal contexts where accurate memory recall by trauma survivors is crucial. However, further research is needed to ensure that the results generalize to risk constellations and more complex, emotionally charged events in clinical samples.

Keywords: Imagery Rescripting, EMDR, Imaginal Exposure, false memory, post-traumatic stress disorder

Introduction

Persistent and distressing emotional memories are closely linked to various psychological disorders, including depression, anxiety disorders, and notably, posttraumatic stress disorder (PTSD). Recently, it has been suggested that treatments aiming to modify these memories, rather than just altering patients' responses to them, might improve long-term therapeutic effectiveness (Kindt & Elsey, 2023). This claim is supported by the fact that consolidated memories can return to a labile state after reactivation. In this labile state, memories can be modified before they are reconsolidated, i.e. re-stabilized (Nader et al., 2000). Experimental studies show that disrupting memory reconsolidation through pharmacological agents (e.g., Kindt & Soeter, 2018; Sevenster et al., 2013) or behavioral tasks (e.g., Golkar et al., 2017; James et al., 2015) can lead to an alteration or *"therapeutic forgetting"* (Kindt & Elsey, 2023) of aversive emotions associated with the memory. Notably, these interventions left declarative aspects (i.e. factual knowledge) of the targeted memories unchanged. This finding has fueled growing interest, particularly in the context of PTSD treatment, in the idea that psychological interventions may induce similar processes, thereby changing the meaning and emotional valence of distressing memories.

However, while changing the emotional quality and meaning of distressing memories offers clinical benefits, there are also concerns about possible disadvantages or unintended side effects. Notably, if memories were altered in a way that impairs accurate recall of factual event details, this could have severe consequences, particularly in legal contexts where accurate witness testimony is crucial (e.g., Ganslmeier et al., 2022, 2023; Otgaar et al., 2021). These concerns are mainly based on a line of experimental research demonstrating that memories are fallible and can be susceptible to various types of errors (Davis & Loftus, 2020). For instance, studies on the so called „misinformation effect" provide evidence that counterfactual information ("misinformation") to which a person is exposed after an event can change or distort the memory of this event (see Loftus & Klemfuss, 2023 for an overview). In these studies, participants typically witness a fictitious event and are later exposed to incorrect information about it. This misinformation is often introduced using suggestive questions (e.g., Loftus, 1997) or post-event narratives presented as authentic accounts of the original event (e.g., Stark et al., 2010). As a result, participants frequently incorporate this misinformation into their recollection of the original event, leading to the formation of false memories (Loftus & Klemfuss, 2023). In line with the Discrepancy Detection Principle (Tousignant et al., 1986), such memory distortions are more likely when an individual fails to identify discrepancies between their recollection of the original event and misinformation that was presented after that event. Factors such as the strength of the original memory, the subtlety of the introduced misinformation, and the presence of warnings regarding misinformation can impact the ability to detect these discrepancies (e.g., Brewin & Andrews, 2017; Leding & Antonio, 2019; Loftus, 1992). Additionally, research on the "imagination inflation effect" (Garry et al., 1996; Goff & Roediger, 1998) indicates that engaging in imagination particularly increases susceptibility to memory errors: Individuals become more confident in the accuracy of their memories when they have vividly imagined or mentally rehearsed an event (e.g., Thomas & Loftus, 2002). This can lead to high levels of confidence in the accuracy of memories for events that have only been imagined but never actually occurred, creating "false memories." Apart from producing false memories for events that have in fact not been experienced (e.g., Mazzoni & Memon, 2003), imagination can also alter existing memories of actually seen objects (Lyle & Johnson, 2007) and actually experienced events (Goff & Roediger, 1998). The Source Monitoring Framework (Johnson et al., 1993; Lindsay & Johnson, 2000) suggests that such inaccurate memory reports arise when a memory of an imagined event (internal source) is erroneously attributed to an actually experienced event (external source). The more perceptual and conceptual detail shared between imagined and experienced events, the greater the risk of these memory errors (Lyle & Johnson, 2007; Thomas et al., 2003).

Against this background, trauma-focused interventions that involve imagination techniques, such as Imaginal Exposure (IE), Eye Movement Desensitization and Reprocessing (EMDR) and Imagery Rescripting (ImRs) have recently received particular attention due to concerns that they might cause unwanted memory alterations. In IE, patients relive the traumatic memory repeatedly in their imagination until the distress declines. IE is assumed to create a new, less distressing memory representation that competes with the original memory during retrieval, without altering the original memory itself (Brewin et al., 1996, 2010; Cooper et al., 2017; Craske et al., 2014). In ImRs, patients reactivate their memory and are then instructed to change the course of events in their imagination so that the outcome is experienced as less distressing (e.g., the perpetrator is confronted and the victim's needs are taken care of, e.g., Arntz & Weertman, 1999). Although the creation of a new memory presentation during rescripting may be a possible mechanism shared by ImRs and IE (Brewin et al., 2010), it has alternatively been suggested that ImRs might change the emotional and cognitive meaning of the original traumatic memory itself, which is then reconsolidated in its modified form (Arntz & Weertman, 1999). In EMDR, patients reactivate their memory and are instructed to simultaneously perform eye movements, typically following the therapist's finger moving horizontally. According to the Working Memory Account (van den Hout & Engelhard, 2012), the memory enters a labile state after memory reactivation during EMDR and is then prone to modifications. The dual task of recalling the memory and simultaneously performing eye movements taxes working memory capacity, resulting in the re-activated memory being recalled and subsequently reconsolidated in a less vivid and emotional form (*"imagination deflation"*, van den Hout & Engelhard, 2012).

In summary, all three interventions involve memory reactivation and imagery, and both factors have been shown in – mostly non-clinical – research to potentially render memories susceptible to changes of factual memory content. Notably, in ImRs, exposure to counterfactual post-event information even constitutes a central element of the rescripting phase and patients are instructed to imagine these changes to the script in a vivid and detailed way (e.g., Arntz, 2012; Dibbets & Arntz, 2016), potentially further reducing the capability of correct source monitoring. Moreover, laboratory studies found that eye-movements performed during memory recall, as found in EMDR, can reduce how vividly memories are recalled (e.g., Kavanagh et al., 2001; Lee & Cuijpers, 2013; Leer et al., 2014). This may impair the ability to accurately detect discrepancies between the original memory and misleading information presented later (see Houben et al., 2018). This concern is supported by research showing that weaker memories, i.e., memories that have faded over time, are particularly prone to distortion (Brewin & Andrews, 2017; Leding & Antonio, 2019; Loftus, 1992). Therefore, EMDR has been proposed to be particularly risky with regard to memory distortions.

Considering the procedural similarities between EMDR, ImRs, IE, and experimental paradigms designed to study memory fallibility, concerns that these interventions could impair memory accuracy are not surprising. However, previous empirical findings offer limited support for these concerns. For example, only few studies have investigated whether IE might negatively impact memory accuracy. Findings from this limited number of studies do not support the claim that IE causes memory impairments as assessed by cued recall tasks (Ganslmeier et al., 2023; Hagenaars & Arntz, 2012; Siegesleitner et al., 2019). Some have even reported improved memory performance following IE as assessed in a free recall task (Ganslmeier et al., 2023). However, as these studies primarily used film clips for memory induction, the impact of IE on more complex, autobiographical memories remains unclear. Interestingly, despite the more explicit instructions to deliberately modify memory content in ImRs and EMDR – such as re-scripting the original scene and reducing its vividness - there is no convincing evidence that these interventions pose a particular risk of distorting factual memory content. In fact, studies on ImRs consistently show no adverse effects on memory accuracy, whether assessed through memory recognition or cued recall tasks (e.g., Aleksic et al., 2024; Ganslmeier et al., 2022, 2023; Hagenaars & Arntz, 2012; Reineck et al., in prep.;

Siegesleitner et al., 2019) or through free recall tasks (Ganslmeier et al., 2022; 2023). On the contrary, ImRs has even been associated with *enhanced* memory performance compared to no intervention control groups (Aleksic et al., 2024; Ganslmeier et al., 2022; Hagenaars & Arntz, 2012; Reineck et al., in prep.). Additionally, prior experimental research investigating specific risk conditions under which ImRs might lead to distortion of factual memory content found that irrespective of the original memory's quality (whether it was complete and clear or less complete and clear, Aleksic et al., 2024), the intervention instructions (whether they involved detailed and vivid imagination or were less vivid and detailed, Aleksic et al., 2024), and the plausibility of the imagined changes (whether they were plausible or less plausible, Reineck et al., in prep.), the risk of memory distortion through ImRs did not increase. Note, however, that most of these earlier studies again used film clips (trauma film paradigm, Holmes & Bourne, 2008) for memory induction (but see Ganslmeier et al., 2022), limiting the generalizability to autobiographical memories, which are more complex, immersive and personally relevant. For EMDR, results regarding potential memory distorting effects are more mixed compared to ImRs: Some previous studies found that eye movements performed during memory reactivation can indeed increase the risk of memory distortion in light of misinformation presented after memory induction and subsequent eye movements (e.g., Houben et al., 2018; Leer & Engelhard, 2020). Additionally, eye-movements have been found to increase the risk of spontaneous false memories, which occur without external suggestive pressure (e.g., Houben et al., 2020). However, these results have not been consistently replicated (e.g., Calvillo & Emami, 2019; van Schie & Leer, 2019). Moreover, some studies assessing memory performance in a stimulus discrimination task found that while eye movements reduced discrimination speed, they did not reduce discrimination accuracy (Leer et al., 2017; van den Hout et al., 2013). Furthermore, the generalizability of previous study results is limited in several aspects. Earlier studies mainly focused on the effects of isolated eye movements (Calvillo & Emami, 2019; Houben et al., 2018a, 2020; Leer & Engelhard, 2020; Kevin van

Schie & Leer, 2019) applied immediately after memory induction (e.g., Houben et al., 2018, 2020a; Leer & Engelhard, 2020), before memory consolidation could take place. In addition, most memories targeted in these studies were relatively simple, such as word lists (e.g., Houben et al., 2020), film clips (e.g., Calvillo & Emami, 2019; Houben et al., 2018) or pictures (e.g., Leer et al., 2017; Leer & Engelhard, 2020), which again limits the generalizability to autobiographical memories. The question thus remains how EMDR affects more complex memories that have already been consolidated.

In summary, there is no evidence that ImRs and IE lead to distortions of factual memory content. The findings for EMDR remain inconclusive, with some studies indicating reduced memory accuracy following eye-movements during memory recall, while other studies could not replicate these results. However, the informative value of prior studies on all three interventions is limited in that they often focused on unconsolidated memories, used simplistic stimuli to induce memories, and employed reductionist intervention protocols, emphasizing the need for further research.

The present study aimed to address some of these limitations. First, in line with Ganslmeier et al. (2022), we tested the intervention effects on more complex and personally relevant memories by using a standardized social stressor for memory induction (see also Freund et al., 2023). Second, to examine the effects of the interventions on the accuracy of sufficiently (re-)consolidated memories, memory induction, intervention and memory test took place in three separate laboratory sessions. Third, we assessed the effects of EMDR using an adapted version of Shapiro's (2001) eight-phase EMDR protocol instead of assessing the effects of isolated eye-movements.

Hypotheses

1. Based on findings that lateral eye movements reduce memory vividness (e.g., Lee & Cuijpers, 2013) and that weaker memories are more prone to errors (e.g., Leding & Antonio,

2019), we expected EMDR to be associated with less accurate memories as compared to ImRs, IE and a no-intervention control group (NIC).

2. Considering the publication of several new studies since the preregistration of this study, all of which consistently found no adverse, but even beneficial effect of ImRs on memory accuracy (Aleksic et al., 2024; Ganslmeier et al., 2022; 2023; Reineck et al., in prep.), we have adjusted our initially preregistered exploratory hypothesis and anticipated that ImRs would result in better memory accuracy compared to IE and NIC.

3. Based on previous findings on the effects of IE on memory accuracy (Ganslmeier et al., 2023; Hagenaars & Arntz, 2012; Houben et al., 2018; Siegesleitner et al., 2019), we expected that IE would lead to better memory accuracy compared to NIC and EMDR.

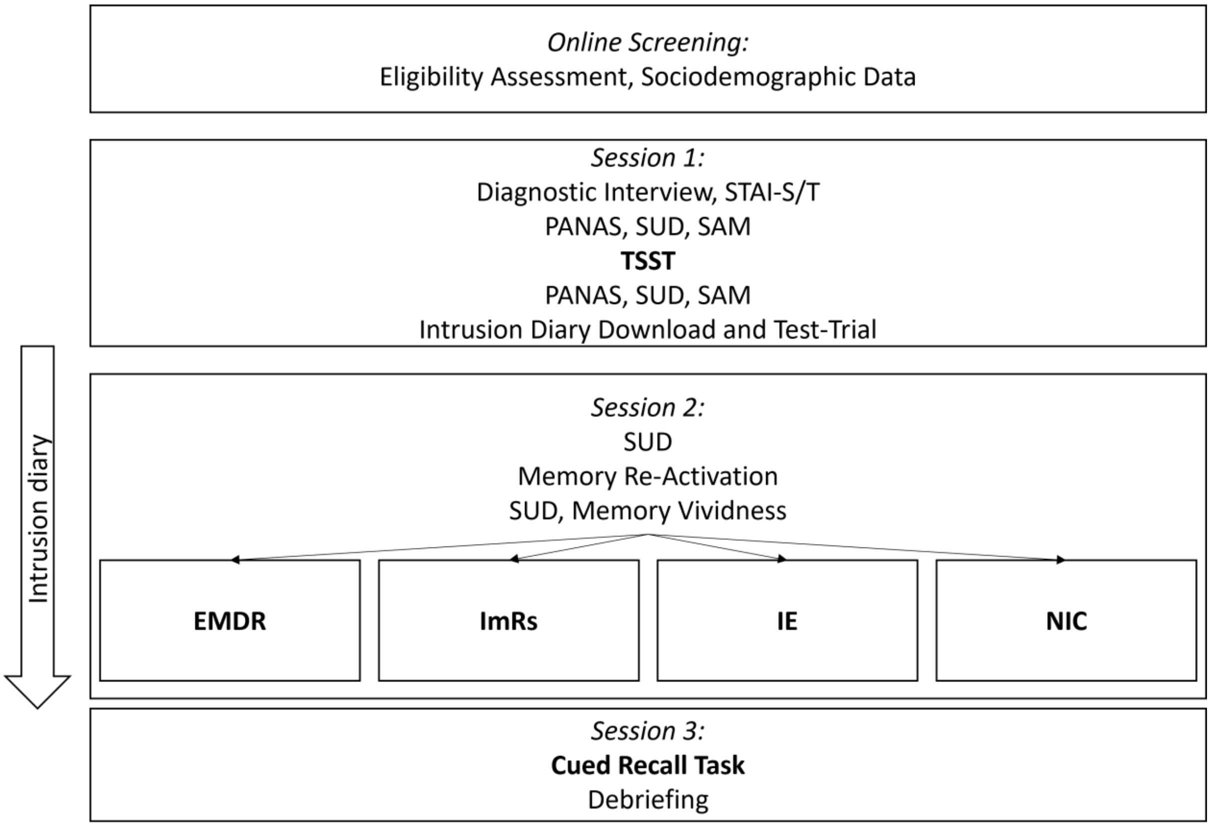
4. Finally, in line with literature on the clinical efficacy of IE (Foa et al., 1999; Powers et al., 2010), EMDR (van den Hout & Engelhard, 2012), and ImRs (Morina et al., 2017), we hypothesized that participants who received one of the three interventions would report fewer intrusive memories related to the TSST in the week following the memory induction than participants who received NIC.

Methods

See Figure 1 for a schematic overview of the study procedure.

Figure 1

Schematic Overview of the Study Procedure



Note. *PANAS* Positive and Negative Affect Schedule, *SUD* Subjective Units of Distress, *SAM* Self-Assessment Manikin, *EMDR* Eye Movement Desensitization and Reprocessing, *ImRs* Imagery Rescripting, *IE* Imaginal Exposure, *NIC* No Intervention Control.

Participants

Several power analyses were conducted to calculate the appropriate sample size with regard to the proposed hypotheses on primary outcome measures (i.e., memory accuracy and intrusive memories): Concerning Hypotheses 1 - 3, previous data had suggested medium sized effects between EMDR and IE (d = 0.88; Houben et al., 2018). Given the exploratory nature of Hypothesis 2 at the time of the study pre-registration, no a priori sample size calculation was possible with regard to the effects of ImRs on memory accuracy in the planning phase of the study. Thus, a sample size calculation (power = 80%, alpha = .05) for Hypothesis 2 with medium effect size (f = 0.25) indicated a total sample size of 128 participants. Considering an expected dropout of 10%, we calculated that 70 participants per condition would suffice to detect statistically significant differences between IE and EMDR on voluntary memory.

Previous studies have suggested medium effects of analogue EMDR (e.g., d = 0.4 - 0.8; Experiment 2 and 3 in van Schie et al., 2019) and ImRs interventions (e.g., d = 0.87; Hagenaars & Arntz, 2012) on intrusive memories compared to no intervention. Based on these findings, a sample size calculation (power = 80%, alpha = .05) for Hypothesis 4 with medium effect size (f = 0.25) indicated a total sample size of 180 participants. Including 10% drop-out, it was expected that 50 participants per condition would suffice to detect statistically significant differences between the three treatment conditions and NIC on involuntary memory. Our target sample size was therefore 280 participants (70 per group), including 10 % drop out.

2,071 participants were recruited through advertisements in online social networks (i.e., Facebook, Instagram, student WhatsApp groups), local newspaper announcements, a public university website and at the local university campus. Exclusion criteria were (a) age below 18 or above 30, (b) current suicidality (QIDS-SR16 item 12 ≥ 2), (c) self-reported current psychological or neurological disorder, (d) history of psychosis or self-injurious behavior, (e) use of beta-blockers or other anti-hypertensive medication, (f) pregnancy, (g) drug intake up to 72 hours before testing, (h) more than three consumptions of alcohol within 24 hours before testing, (i) prior participation in studies using a similar stress induction. Inclusion criteria were social anxiety (SIAS > 24) and sufficient German language proficiency.

Based on these criteria, 786 participants were excluded in the online screening. Another 471 participants did not finish the screening questionnaire. 484 participants did not respond to the study invitation after completing the online screening. We had to exclude an additional 63 participants who fulfilled the exclusion criteria as assessed by the diagnostic interview conducted in Session 1. Two additional participants were excluded in Session 1 as they were familiar with the TSST task. 11 participants dropped out during Session 1 after withdrawing from the TSST task, one participant dropped out after completing Session 1. The final sample consisted of 253 participants (192 females, 59 males, 2 non-binary, mean age = 22.16, SD = 3.15, range = 18 to 30; 77,47 % of German nationality).

Participants were randomly allocated to one of three intervention conditions (ImRs, IE, EMDR) or to NIC. They received partial course credit or a monetary reimbursement (50 € for complete study participation).

Materials

All materials are available at the Open Science Framework (https://osf.io/h3c7w/).

Trier Social Stress Test

An adapted version of the Trier Social Stress Test (Kirschbaum et al., 1993), a standardized psychosocial stressor, was used to experimentally induce (an experimental analogue for) a memory of an aversive autobiographical life event (see e.g., Freund et al., 2023; Ganslmeier et al., 2022; Stanek et al., 2024). For this purpose, participants were instructed that a mock job interview with a jury would take place and they were given three minutes to prepare a speech about their suitability for their dream job, focusing on their personal strengths and weaknesses. After that, they were accompanied to a different room where the TSST took place. Participants were then asked to (a) give a 5-min presentation about their strengths and weaknesses, (b) do a surprise mathematical exercise (counting backwards in steps of 13, starting at 1,310), and (c) sing a musically demanding song (‘I will always love you’, Dolly Parton, 1974) in front of a stern evaluative jury consisting of one male and one female judge (Duchesne et al., 2012). To increase the aversiveness of the situation, a camera was placed in front of participants and they were misled to think that they were filmed and that their performance would later be evaluated. The jury was trained to provide standardized verbal instructions to the participants and to refrain from any further verbal or non-verbal feedback.

Interventions

Participants in the intervention groups received one single intervention session on the day after memory induction. All interventions were provided by post-graduate clinical trainees (CBT) with more than two years of clinical training. All investigators received supervision provided by LW and met for supervision sessions on a regular basis.

Memory reactivation task

In order to reactivate the emotions sufficiently to address them in treatment, all interventions (ImRs, IE, EMDR) were preceded by a short imagery exercise (see Kunze et al., 2017). Participants were first instructed to close their eyes and to reactivate the beginning of the scene until the worst part of their memory ("hotspot") was reached. Before and after the short reactivation they rated their subjective distress and memory vividness (see Table 2 for descriptive statistics). They then proceeded with the respective intervention. All interventions took place until a reduction of subjective distress to 1 or lower on a scale from 0 - 10 had been reached, but at least for a minimum of 35 minutes and up to a maximum of 60 minutes. The exact wording of the instructions for memory reactivation can be found on the OSF (https://osf.io/h3c7w/).

Imagery Rescripting

The ImRs protocol was adapted from Arntz and Weertman (1999; see Kunze et al., 2017). The intervention started with a short explanation of the rationale. After a brief memory reactivation, participants were asked to change the course of events in their imagination in a way that the outcome of the scene felt less distressing to them. For example, participants imagined how they stood up against the jury and how a friend entered the scene to provide emotional support. During the imagination, the investigator asked in-depth questions, e.g., about sensory perceptions, thoughts, emotions, and bodily sensations. Once participants indicated that they were completely satisfied with the outcome of the situation (or when the maximum duration of 60 minutes was reached), ImRs was concluded. The exact wording of the instructions for ImRs can be found on the OSF (https://osf.io/h3c7w/).

EMDR

We used an adapted version of the EMDR protocol used in the IREM study (Boterhoven De Haan et al., 2020). The protocol consisted of 6 phases: 1) short explanation of the rationale, 2) preparation phase, 3) target assessment, 4) desensitization and reprocessing, 5) introduction and installation of the positive cognition and 6) body check. The installation of the positive cognition was only introduced when a reduction of subjective distress to 2 or lower on a scale from 0-10 had been reached in the desensitization phase. The eye movements were induced using the EMDR kit, version 2.0 (see https://www.emdrkit.com). A white dot, moving from horizontally (speed: 1 Hz in the Desensitization Phase, 0.3 Hz during installation of the positive cognition; 1 Hz equals one complete horizontal eye movement in one second), was presented on a light bar (length: 70 cm) during multiple episodes of a minimum of 24 *s* each. The investigators were asked to monitor the participants' eye movements to ensure compliance with the eye movement instructions. Detailed instructions are provided on the OSF (https://osf.io/h3c7w/).

Imaginal Exposure

The IE intervention used in the study was adapted from Foa and Rothbaum (1989) and consisted of a short explanation of the rationale and imaginal exposure to the TSST situation. After memory reactivation, participants were asked to imagine the entire TSST scene as vividly as possible. As in ImRs, they were encouraged to focus on and report about any sensory perceptions, thoughts, emotions and bodily sensations they experienced throughout the imagination. Detailed instructions are provided on the OSF (https://osf.io/h3c7w/).

No-intervention control (NIC)

Participants in the NIC group did not receive any intervention and therefore only returned to the laboratory one week after the first session.

Measures

Screening measures to establish eligibility and assess sample characteristics

Demographic questionnaire

Demographic information (age, gender, nationality, highest level of education, current employment) was assessed to obtain sample characteristics.

Health status questionnaire

A short health questionnaire was administered to gather information about participants' sleep quality and duration, drug and alcohol consumption in the days prior to the study, neurological disorders and cardiovascular diseases.

Depressive symptoms

The Quick Inventory of Depressive Symptomatology (16-Item; Self-Report; QIDS-SR16, Rush et al., 1996; German translation by Roninger et al., 2015) was administered to assess depressive symptoms.

Social anxiety

We used the Social Interaction Anxiety Scale (SIAS; Mattick & Clarke, 1998; Stangier et al., 1999) to assess social anxiety. Trait and state anxiety were assessed using the State-Trait-Anxiety-Inventory (STAI-S/T, Spielberger et al., 1970; German translation by Laux et al., 1981).

Manipulation Checks

Induction of an aversive autobiographical memory using the TSST

To check whether the TSST was experienced as distressing (in order to create an aversive autobiographical memory), all relevant variables were measured immediately before (but before any mention of the upcoming task) and after the TSST. The Positive and Negative Affect Schedule (PANAS; German version: Krohne et al., 1996) was used to assess mood. Additionally, subjective distress (SUD) was assessed by visual analogue scales on a scale ranging from 0 to 10. Subjective arousal was assessed using Self-Assessment Manikins (SAM; Bradley & Lang, 1994).

Memory reactivation pre- intervention and distress reduction post – intervention

To check whether memory reactivation was successful, we assessed memory vividness on a scale ranging from 0 – 10 post memory reactivation, as well as SUD pre- and post memory reactivation. The same measures were assessed at the end of each intervention.

Outcome measures

Memory accuracy - Cued recall task

Memory accuracy was assessed by means of a cued recall task comprising 30 questions with one true and three false answer options (e.g., “What colors were the jury’s members’ shirts?”; true answer: black and orange, false answers: pink and black; orange and blue; blue and pink). Following Ganslmeier et al. (2022), questions were chosen based on a guideline for police examinations (Hermanutz & Schröder, 2015) and focused on the place of action (e.g., “What was on the jury’s table?”), the persons involved (e.g., “What kind of haircut did the female judge have?”) and the events taking place in the TSST (e.g., “What kind of feedback did you receive during the arithmetic task?”). The total number of correct answers constituted the primary outcome measure for voluntary memory. The stimulus material used in the memory recognition task was piloted in order to ensure appropriate difficulty of the items to avoid ceiling effects (i.e., we aimed for an approximately balanced number of items across different levels of difficulty ranging from very difficult to very easy, and replaced items where necessary to meet this criterion).

Memory confidence

In legal practice, the evaluation of eyewitness credibility and the accuracy of testimonies often relies, at least partly, on assessing memory confidence (Brewer & Burke, 2002; Busey et al., 2000). However, research indicates that memory accuracy and memory confidence may not necessarily be linked (Odinot et al., 2013; Roediger et al., 2012) and suggests that trauma-focused psychological interventions may have distinct effects on measures of objective memory accuracy versus subjective memory confidence. Therefore, we additionally assessed memory confidence for exploratory analyses. After answering each item of the memory recognition task, participants were asked to indicate how confident they were in having correctly answered the respective question *("How sure are you that you remembered the answer to this question correctly?"*) on a scale from 0 (not at all sure) to 10 (absolutely sure) on a visual analogue scale.

Intrusive memories - Intrusion diary

The quantity (total number) and quality (type of memory as defined below; content of the memory; trigger situation; distress and vividness, each scored on a scale from 0 (not at all) – 10 (very much) of intrusive memories of the TSST situation were assessed the day before – and during 7 days after the intervention by means of an app-based intrusion diary using the services of the software developer m-Path (m-Path, 2021). Intrusive memories were defined as spontaneously occurring involuntary memories of the TSST event, which could be mental images, sounds, verbal thoughts, emotions, bodily sensations or a combination. Participants were instructed to register all involuntary memories in the app immediately upon occurrence.

The total number of intrusive memories during the week following the intervention constituted the primary outcome variable for involuntary memory.

To ensure that potential group differences can not be explained by differences in compliance with the intrusion diary, we performed a compliance check for intrusion diary adherence. Subjective compliance was assessed at post-study assessment with the question *"Please indicate how the following statement applies to you: I have often been unable/forgotten to enter my involuntary memories into the diary"* on a visual-analogue scale from "not at all" = 0 to "very often" = 10 (cf. Holmes et al., 2004).

Procedure

Online Screening

Participants were given an overview of the study procedure and the requirements for study participation via an online form. They were informed that a challenging task which could potentially elicit distress would be part of the study and that they could withdraw from study participation at any time. After providing informed consent, participants were directed to a brief online screening where basic inclusion criteria were assessed. Those meeting inclusion criteria provided sociodemographic data (age, gender, education, nationality) and were invited to the first experimental session. Participants not meeting the inclusion criteria were not invited to attend future appointments.

Session 1

At the beginning of the first session, participants completed a standardized diagnostic interview and a questionnaire to assess exclusion criteria related to psychological disorders. Those meeting exclusion criteria were excluded and compensated for their time. Eligible participants next completed the short health questionnaire. Participants then filled out the STAI-S/-T and proceeded with the pre -TSST assessment of PANAS and SUD. After that, participants were provided with pre -TSST instructions and given 3 min to prepare a 5-min presentation of their strengths and weaknesses, which they were to present in front of a jury later. Participants were then accompanied to another room where the TSST took place. Following the TSST, participants were brought back and asked to fill out post-assessments of PANAS and SUD. At the end of the session, subjects were assisted in downloading the m-path app, received instructions on how to use the intrusion diary, and ran a test trial in the presence of the experimenter. Participants were then randomly allocated to one of the four experimental conditions. Those in the intervention conditions attended a second session the next day, while those in NIC returned one week later.

Session 2

The second session began with the completion of the health questionnaire for assessment of prior drug consumption and hours of sleep. In preparation of the following interventions, participants were then provided with a demonstration of an imagery exercise by the experimenter (imagination of today’s breakfast, see Strohm et al., 2021). Following the imagery exercise, the session proceeded with pre-memory reactivation assessments of SUD and memory vividness, followed by the brief imagery exercise to reactivate their memory. After the imagery exercise, participants completed post-assessments of SUD and memory vividness. This was followed by the interventions (EMDR, ImRs, or IE). SUD and memory vividness were again assessed at the end of the interventions and when the session concluded.

Session 3

Session 3 started with the health questionnaire for assessment of prior drug consumption and sleep, followed by the cued recall task which participants completed on the computer. Session 3 ended with a debriefing of the participants and reimbursement for study participation.

Statistical Analyses

All analyses described below were conducted in R (R Core Team, 2023). R Code for the analyses as well as the data set and corresponding codebook can be found on the OSF (https://osf.io/h3c7w/).

Baseline Differences

To identify possible covariates, three univariate ANOVAs on QIDS-SR16 and STAI-S/T pre-TSST were conducted in order to assess differences between the four groups (ImRs, EMDR, IE, NIC).

Manipulation Checks

Emotional distress caused by the TSST

To check whether the TSST was experienced as distressing, four 2 (pre-TSST vs. post-TSST) x 4 (EMDR vs. IR vs. IE vs. NIC) mixed ANOVAs were conducted for SUD-ratings, SAM-ratings and for the two PANAS-subscales as dependent variables.

Memory Reactivation pre-intervention in Session 2

To assess whether the memory was sufficiently reactivated before the interventions, one 2 (pre-reactivation vs. post-reactivation) x 4 (EMDR vs. IR vs. IE vs. NIC) mixed measures ANOVA was conducted for SUD ratings. In addition, group differences in vividness ratings after memory reactivation were assessed with a univariate ANOVA.

Analyses of primary hypotheses

Group differences in memory accuracy

To assess differences in memory accuracy between the four groups, a univariate ANOVA was carried out on the number of correct answers in the cued recall task. Pairwise post-hoc tests were conducted to examine possible hypothesized group differences (i.e., EMDR vs. NIC, EMDR vs. IE, ImRs vs. IE, ImRs vs. NIC).

Group differences in intrusive memories

Note that due to a violation of the normality assumption we deviated from the pre-registered use of univariate ANOVAs to assess group differences in the baseline number of intrusive memories recorded between Session 1 and Session 2 (pre-intervention) and the mean number of intrusive memories reported between Session 2 and Session 3 (post-intervention). Instead, Kruskal-Wallis tests were carried out to investigate differences in the number of intrusive memories between the three interventions and NIC for pre- and post-intervention.

Additionally, to examine the course of intrusive memory occurrence, a two-level Poisson Regression Model with random intercepts and random slopes was estimated. Intrusive memories were predicted by Time (Level 1, within-subject), Condition (Level 2, between-subjects), and their cross-level interactions (Siegesleitner et al., 2019). NIC and intrusive memories on Day 1 (pre-intervention) were used as reference levels.

Group differences on the number of participants who did not develop any intrusive memories at post-TSST or showed no intrusive memories post-intervention were explored using chi-square tests (Siegesleitner et al., 2019).

Exploratory analyses

Memory confidence

To explore group differences in memory confidence ratings, a multivariate analysis of variance (MANOVA) was carried out on mean confidence ratings for correct answers and for wrong answers as dependent variables.

Intrusion distress and intrusion load

As intrusive memories which are perceived as distressing are especially relevant in the context of PTSD (Michael et al., 2005; Steil & Ehlers, 2000), we exploratively assessed the intervention effects on intrusion distress and intrusion load (number of intrusive memories weighed for their distress) in addition to the total number of intrusive memories. Two two-level Poisson Regression Models with random intercepts and random slopes were estimated for intrusion distress and intrusion load. Intrusion distress and intrusion load were predicted by Time (Level 1, within-subject), Condition (Level 2, between-subjects), and their cross-level interactions. NIC and intrusion distress/ intrusion load on day 1 (pre-intervention) were used as reference levels.

For effect sizes, 95% confidence intervals were computed. Bonferroni corrections were conducted for post-hoc tests.

Results

Baseline and control variable differences between conditions

As illustrated in Table 1, there were no significant differences between the four groups in terms of sociodemographic or control variables. The duration of the intervention differed significantly between groups, F (2, 173) = 24.11, $p < .001$. Post hoc Tukey's HSD test revealed that the duration of ImRs was significantly shorter than EMDR and IE, both $p_{adj.} < .001$. No difference was found between IE and EMDR, $p_{adj} = 0.19$.

Table 1

Sociodemographic and Control Variables

Variables	Condition				Statistics	P
	EMDR (*n* = 62)	ImRs (*n* = 62)	IE (*n* = 63)	NIC (*n* = 66)		
Sociodemographic Variables						
	M(SD)	*M(SD)*	*M(SD)*	*M(SD)*		
Age	21.71 (3.27)	22.37 (3.23)	22.33 (3.08)	22.21 (3.04)	F(3,249) = 0.58	.63
Number of years of education	15.00 (2.76)	14.87(3.11)	14.92 (3.07)	14.75 (2.82)	F(3,248) = 0.08	.97
	%	%	%	%		
Gender (female)	74,19	74,19	77,78	77,27	$\chi^2(6) = 2.26$	.89
German (yes)	72,58	79,03	82,54	75,76	$\chi^2(3) = 1.97$	.58
Student (yes)	95,15	91,93	88,89	93,94	$\chi^2(3) = 2.04$	.56
Control Variables						
	M(SD)	*M(SD)*	*M(SD)*	*M(SD)*		
Sleep before Session 1	7.55 (0.86)	7.34 (1.28)	7.34(1.29)	7.41(1.18)	F(3,248) = 0.45	.72
Sleep before Session 2	7.45 (1.02)	7.44 (1.22)	7.06 (1.44)	-	F(2,183) = 1.94	.15
Sleep before Session 3	7.39 (1.37)	7.27 (1.23)	6.97 (1.52)	7.29 (1.33)	F(2,249) = 1.10	.35
QUIDS-SR-16	4.60 (2.27)	5.19 (2.8)	4.87 (2.80)	5.08 (2.35)	F(3,249) = 0.65	.59
STAI-T	37.81 (7.33)	39.31 (7.31)	38.37 (8.56)	39.80 (7.54)	F(3,249) = 0.87	.46
STAI-S	38.29 (7.95)	38.95 (8.23)	38.13(8.27)	38.45 (7.92)	F(3,249) = 0.12	.95
Compliance Intrusion Diary	21.36 (25.86)	25.58 (29.83	18.22 (25.72)	21.36 (25.8)	F(3,249) = 2.06	.11
Duration memory reactivation (in min.)	8.12 (2.97)	8.63 (2.86)	8.98 (2.69)	-	F (2,173) = 1.36	.26
Duration intervention (in min.)	50.97 (11.99)	42.22 (8.53)	54.11 (7.84)	-	F (2, 173) = 24.11	< .001

Note. ImRs Imagery Rescripting, *EMDR* Eye Movement Desensitization and Reprocessing, *IE* Imaginal Exposure, *NIC* No-Intervention Control, *QIDS-SR-16* Quick Inventory of Depressive Symptomatology, *STAI-S/T* State/ Trait Form of the State-Trait-Anxiety-Inventory, *M* Mean, *SD* Standard Deviation.

Manipulation checks

Descriptive statistics of all manipulation check scores for SUD, SAM, vividness, and PANAS are displayed in Table 2.

Table 2

Descriptive Statistics of Manipulation Check Variables

Variables	Condition			
	EMDR (*n* = 62)	ImRs (*n* = 62)	IE (*n* = 63)	NIC (*n* = 66)
	M(SD)	*M(SD)*	*M(SD)*	*M(SD)*
Session 1				
SUD pre TSST	3.18 (2.52)	3.47 (2.45)	3.73 (2.44)	3.08 (2.43)
SUD post TSST	5.79 (2.50)	5.43 (2.80)	6.21 (2.89)	6.23 (2.39)
SAM pre TSST	3.89 (1.72)	3.97 (1.92)	3.92 (1.75)	4.06 (1.78)
SAM post TSST	6.61 (1.40)	6.29 (1.77)	6.57 (1.86)	6.71 (1.54)
Negative affect pre TSST (PANAS)	13.81 (3.98)	13.95 (4.16)	12.78 (3.10)	13.56 (3.23)
Negative affect post TSST (PANAS)	21.61 (6.91)	20.13 (6.04)	20.81 (8.17)	20.85 (6.55)
Positive affect pre TSST (PANAS)	28.76 (6.51)	28.16 (6.25)	27.48 (6.97)	28.46 (6.28)
Positive affect post TSST(PANAS)	27.82 (7.51)	26.84 (8.08)	27.08 (7.19)	28.14 (7.81)
Session 2				
SUD pre reactivation	2.68 (2.04)	2.71 (2.00)	3.19 (2.31)	-
SUD post reactivation	5.83 (2.02)	5.47 (2.19)	5.95 (2.77)	-
Vividness post reactivation	7.28 (1.28)	6.88 (1.55)	7.39 (1.60)	-

Note. *ImRs* Imagery Rescripting, *EMDR* Eye Movement Desensitization and Reprocessing, *IE* Imaginal Exposure, *NIC* No-Intervention Control, *SUD* Subjective Stress, *SAM* Self-Assessment Manikins, *M* Mean, *SD* Standard deviation.

Emotional distress caused by the TSST

A significant main effect was found for time, indicating an increase of subjective distress (SUD), subjective arousal (SAM), and negative affect from pre- to post-TSST, (SUD: $F(1, 246) = 163.903$, $p < 0.001$, $\eta_p^2 = 0.4$, 95% *CI* [0.31, 0.48]; SAM: $F(1, 248) = 460.513$, $p < 0.001$, $\eta_p^2 = 0.65$, 95% *CI* [0.58, 0.70]; negative affect: $F(1, 249) = 280.714$, $p < 0.001$, $\eta_p^2 = 0.53$, 95% *CI* [0.45, 0.59]). No main effects emerged for intervention (all *Fs* < 87, all *ps* > .46, all $\eta_p^2 < 0.01$). No interaction effects between time and intervention (all *Fs* < 1.40, all *ps* > .24, all $\eta_p^2 < 0.02$) were observed in these analyses.

Regarding positive affect, no main effects of time, $F(1, 249) = 2.981$, $p = 0.09$, $\eta_p^2 = 0.01$ *CI* [0.00; 0.05] and intervention, $F(3, 249) = 0.46$, $p = 0.71$, $\eta_p^2 = 0.005$ *CI* [0.00; 0.02], and no interaction effect, $F(3, 249) = 0.303$, $p = 0.82$, $\eta_p^2 = 0.004$ *CI* [0.00; 0.02], were found, indicating that there was no decrease of positive affect from pre-to post-TSST.

Memory Reactivation pre-intervention in Session 2

Subjective distress

Eleven participants (IR: 3, IE: 5, EMDR: 2) had to be excluded from these analyses as data on subjective distress were mistakenly not assessed by the experimenters for these participants. A mixed ANOVA revealed a large main effect of time with higher post- than pre-memory reactivation SUD scores, $F(1, 173) = 332.10$, $p < .001$, $\eta_p^2 = 0.66$, 95% *CI* [0.58, 0.71]. There was no significant main effect of intervention, $F(2, 173) = 0.875$, $p = .42$, $\eta_p^2 = 0.01$, 95% *CI* [0.00, 0.05], nor a significant interaction effect $F(2, 173) = 0.69$, $p = .51$, $\eta_p^2 = 0.01$, 95% *CI* [0.00, 0.04].

Memory vividness

A univariate ANOVA revealed no significant group differences in memory vividness post-reactivation, $F(2, 172) = 1.91$, $p = .15$, $\eta_p^2 = 0.02$, 95% *CI* [0.00, 0.07].

Main analyses

Descriptive statistics for the results of the main analyses are displayed in Table 3.

Table 3

Descriptive Statistics of Main Outcome Variables

Variables	Condition			
	EMDR (*n* = 62)	ImRs (*n* = 62)	IE (*n* = 63)	NIC (*n* = 66)
Memory Recognition Task				
	M(SD)	*M(SD)*	*M(SD)*	*M(SD)*
Relative Number of right answers	0.57 (0.08)	0.58 (0.1)	0.60 (0.08)	0.57 (0.08)
Confidence right answers	70.93 (9.59)	69.48 (10.10)	71.28 (9.45)	69.57 (11.15)
Confidence wrong answers	46.02 (11.15)	41.05 (14.99)	44.52 (13.15)	45.08 (13.36)
Intrusions				
	n (%)	*n* (%)	*n* (%)	*n* (%)
Participants who reported no intrusion after Session 1	17 (27.42)	18 (29.03)	12 (19.05)	17 (25.76)
Participants who reported no intrusion after Session 2	19 (30.65)	16 (25.81)	27 (42.86)	21 (31.82)
	M(SD)	*M(SD)*	*M(SD)*	*M(SD)*
Number of intrusions pre-intervention	1.97 (2.31)	2.08 (2.44)	2.11 (1.74)	1.70 (2.01)
Number of intrusions post-intervention	1.69 (2.01)	2.24 (2.41)	2.49 (4.33)	2.35 (4.10)
Number of intrusions day 1	1.97 (2.31)	2.08 (2.44)	2.11 (1.74)	1.70 (2.01)
Number of intrusions day 2	0.87 (1.17)	0.95 (1.36)	1.16 (2.50)	0.65 (1.12)
Number of intrusions day 3	0.37 (0.71)	0.44 (0.67)	0.37 (0.68)	0.41 (0.74)
Number of intrusions day 4	0.21 (0.48)	0.19 (0.44)	0.40 (0.73)	0.46 (1.06)
Number of intrusions day 5	0.10 (0.30)	0.24 (0.50)	0.18 (0.49)	0.27 (0.65)
Number of intrusions day 6	0.07 (0.25)	0.19 (0.40)	0.21 (0.51)	0.23 (0.74)
Number of intrusions day 7	0.08 (0.28)	0.23 (0.50)	0.19 (0.47)	0.33 (0.92)

Note. *ImRs* Imagery Rescripting, *EMDR* Eye Movement Desensitization and Reprocessing, *IE* Imaginal Exposure, *NIC* No-Intervention Control, *SUD* Subjective Stress, *SAM* Self-Assessment Manikins, *M* Mean, *SD* Standard Deviation.

Memory accuracy

Descriptive statistics for cued recall task responses are presented in Table 3. There were no statistically significant differences between group means in the relative number of correct answers as determined by the one-way ANOVA, $F(3, 249) = 2.293$, $p = 0.08$, $\eta^2 = 0.03$, 95 % CI [0.0, 0.07].

Intrusive memories

Baseline number of intrusive memories (pre-intervention)

No significant differences were observed in the baseline number of intrusive memories as determined by the Kruskal-Wallis test, $H(3) = 253$, $p = 0.30$, $\eta^2 < 0.0$. $\chi2$ test revealed that the number of participants who did not develop any intrusive memories between Session 1 and Session 2 did not differ between groups, $\chi2(3) = 1.92$, $p = .59$.

Number of intrusive memories post intervention

No significant differences were observed in the number of intrusive memories post-intervention as determined by the Kruskal-Wallis test, $H(3) = 253$, $p = 0.59$, $\eta^2 < 0.0$. $\chi2$ test revealed that the number of participants who did not report any intrusive memories post-intervention did not differ between groups, $\chi2(3) = 4.43$, $p = .22$.

Development of intrusive memories over time

Contrary to our expectations, only participants who had received EMDR showed a significantly greater reduction of intrusive memories over time compared to NIC. No differences were found between ImRs and NIC, nor between IE and NIC (See Table 4).

Table 4

Multilevel Poisson Regression Model Predicting the Number of Intrusive Memories with the Predictors Time, and Intervention (NIC, EMDR, ImRs, IE)

Predictor	Estimates (SE)	95% CI	z	p
(Intercept)	0.62 (0.18)	[0.27; 0.95]	3.52	< .001
time	- 0.56 (0.18)	[-0.68; -0.43]	-8.71	< .001
NIC vs. EMDR	0.64 (0.23)	[0.19; 1.09]	2.780	< .001
NIC vs. ImRs	0.29 (0.23)	[-0.16; 0.74]	1.28	.201
NIC vs. IE	0.45 (0.23)	[0.00; 0.89]	1.98	.048
time : EMDR	-0.27 (0.09)	[-0.44; -0.10]	-3.15	.002
time: ImRs	-0.04 (0.08)	[-0.20; 0.11]	-0.56	.578
time: IE	-0.12 (0.08)	[-0.28; 0.04]	-1.48	.140

Note. ImRs Imagery Rescripting, *EMDR* Eye Movement Desensitization and Reprocessing, *IE* Imaginal Exposure, *NIC* No-Intervention Control.

Exploratory analyses

Memory confidence rating

Regarding memory confidence ratings, the MANOVA did not reveal significant group differences in the mean confidence ratings for right and wrong answers, $F(3, 249) = 1.07$, $p = .38$, $\eta_p^2 = 0.01$, 95% *CI* [0.00, 0.03], Pillai's Trace = 0.03. See Table 3 for descriptive statistics.

Intrusion characteristics

We found no significant effect of time for intrusion distress. The reduction of intrusion distress was significantly greater in EMDR and in IE as compared to NIC. ImRs did not significantly differ from NIC in the reduction of intrusion distress. Similarly, we found no significant effect of time for intrusion load. The reduction of intrusion load was significantly greater in EMDR and in IE as compared to NIC. ImRs did not significantly differ from NIC in the reduction of intrusion load. For coefficient estimates, confidence intervals, and test statistics see Table 5 for intrusion distress and Table 6 for intrusion load. Descriptive statistics can be found in Table 7.

Table 5

Multilevel Poisson Regression Model Predicting Intrusion Distress with the Predictors Time, and Intervention (NIC, EMDR, ImRs, IE)

Predictor	Estimates (SE)	95% CI	t	p
(Intercept)	39.27 (3.54)	[32.33; 46.21]	11.11	< .001
time	-1.45 (0.95)	[-3.31; 0.41]	-1.53	.128
NIC vs. EMDR	12.73 (5.08)	[2.77; 22.69]	2.51	.012
NIC vs. ImRs	0.97 (4.98)	[-8.79; 10.74]	0.20	.845
NIC vs. IE	14.88 (4.89)	[5.29; 24.46]	3.05	.002
time : EMDR	-5.49 (1.54)	[-8.51; -2.47]	-3.56	<.001
time: ImRs	-2.01 (1.33)	[-4.62; 0.59]	-1.52	.130
time: IE	-4.04 (1.34)	[-6.68; -1.41]	-3.01	.003

Note. ImRs_Sensory Imagery Rescripting with sensory-perceptual focus, *ImRs_NotSensory* Imagery Rescripting without sensory-perceptual focus, *NIC* no-intervention control group.

Table 6

Multilevel Poisson Regression Model Predicting Intrusion Load with the Predictors Time, and Intervention (NIC, EMDR, ImRs, IE)

Predictor	Estimates (SE)	95% CI	t	p
(Intercept)	105.56 (21.04)	[64.26; 146.85]	5.02	< .001
time	-8.99 (5.05)	[-18.89; 0.92]	-1.78	.075
NIC vs. EMDR	62.53 (29.58)	[4.48; 120.58]	2.11	.035
NIC vs. ImRs	10.22 (29.54)	[-47.75; 68.18]	0.35	.730
NIC vs. IE	46.73 (29.30)	[-10.76; 104.21]	1.60	.111
time : EMDR	-29.00 (7.61)	[-43.93; -14.08]	-3.81	<.001
time: ImRs	-11.45 (7.04)	[-25.27; 2.36]	-1.63	.104
time: IE	-15.55 (7.08)	[-29.44; -1.67]	-2.20	0.028

Note. ImRs_Sensory Imagery Rescripting with sensory-perceptual focus, *ImRs_NotSensory* Imagery Rescripting without sensory-perceptual focus, *NIC* no-intervention control group.

Table 7

Descriptive Statistics of Exploratory Analyses

Variables	Condition			
	EMDR (*n* = 62)	ImRs (*n* = 62)	IE (*n* = 63)	NIC (*n* = 66)
	M(SD)	*M(SD)*	*M(SD)*	*M(SD)*
Intrusion distress pre-intervention	49.90 (25.48)	38.40 (22.76)	51.08 (29.47)	43.25 (26.25)
Intrusion distress post-intervention	29.99 (23.30)	23.56 (22.88)	33.05 (25.26)	36.14 (23.92)
Intrusion distress day 1	49.90 (25.48)	38.40 (22.76)	51.08 (29.47)	43.25 (26.25)
Intrusion distress day 2	32.43 (25.67)	25.31 (22.98)	39.00 (26.22)	35.47 (21.77)
Intrusion distress day 3	29.39 (23.83)	16.89 (15.68)	28.04 (23.46)	30.07 (26.15)
Intrusion distress day 4	24.39 (17.37)	19.75 (24.62)	29.52 (24.49)	32.93 (20.12)
Intrusion distress day 5	25.33 (20.51)	27.00 (25.18)	20.73 (19.52)	38.22 (25.17)
Intrusion distress day 6	32.50 (21.99)	20.67 (20.76)	27.85 (25.85)	38.60 (25.56)
Intrusion distress day 7	24.60 (14.14)	31.14 (30.76)	30.67 (23.70)	46.33 (26.93)
Intrusion load day 1	254.89 (234.91)	179.72 (110.20)	176.11 (116.37)	199.41 (223.87)
Intrusion load day 2	79.91 (78.38)	50.75 (35.72)	175.27 (136.88)	98.16 (102.27)
Intrusion load day 3	51.00 (33.86)	24.56 (25.31)	45.09 (41.04)	50.44 (49.20)
Intrusion load day 4	30.69 (22.05)	19.75 (24.62)	42.76 (34.94)	99.87 (85.86)
Intrusion load day 5	25.33 (20.51)	36.27 (31.26)	26.00 (17.54)	78.78 (67.60)
Intrusion load day 6	32.50 (21.99)	20.67 (20.76)	42.62 (30.68)	97.53 (72.44)
Intrusion load day 7	24.60 (14.14)	42.43 (54.06)	42.58 (37.03)	149.95 (122.16)

Note. ImRs Imagery Rescripting, *EMDR* Eye Movement Desensitization and Reprocessing, *IE* Imaginal Exposure, *NIC* No-Intervention Control, *M* Mean, *SD* Standard Deviation.

Discussion

The aim of the present three-day experimental study was to investigate the effects of trauma-focused psychological interventions, namely EMDR, ImRs, and IE, on the accuracy of voluntarily retrieved aversive memories. In order to control and manipulate memory content, we used a standardized social stressor, the TSST, to induce an aversive emotional memory. Contrary to our predictions, the intervention groups did not differ with regard to their effects on memory accuracy from a NIC. Specifically, we did not find that ImRs was associated with better memory accuracy compared to IE and NIC, nor did we find that EMDR was associated with less accurate memories compared to IE and NIC. Furthermore, we did not find any group differences in mean memory confidence ratings. Surprisingly, when looking at intervention effectiveness, the intervention groups did not demonstrate a greater reduction in the number of intrusive memories of the TSST compared to the NIC group. However, we did observe that EMDR and IE were associated with a greater reduction in intrusion distress and intrusion load than NIC.

Effects of Imagery Rescripting (ImRs)

We expected that ImRs would be associated with better memory accuracy compared to EMDR and NIC. We had based this assumption on previous studies which predominantly found improved memory accuracy after ImRs (Aleksic et al., 2024; Ganslmeier, 2022; Hageaars & Arntz, 2012; Reineck et al., 2024, but see Ganslmeier et al., 2023). Contrary to this expectation, we found no difference in memory accuracy between ImRs and the other conditions, which contradicts our hypothesis that ImRs would *enhance* memory accuracy. However, this result also challenges widespread concerns that ImRs may *reduce* memory accuracy (e.g., Otgaar et al., 2021). This finding is consistent with theoretical assumptions about the working mechanisms of ImRs, suggesting that it might selectively alter the meaning of distressing memories while preserving memory of factual event details (e.g., Arntz, 2012).

One possible explanation for the fact that ImRs did not improve memory accuracy in the present study is that the intervention might not have been potent enough to yield beneficial effects in both reducing intrusive memories and enhancing voluntary memory. This is suggested by the fact that ImRs also did not lead to a reduction in the number of intrusive memories, intrusion distress, or intrusion load compared to NIC. Furthermore, the beneficial effects of ImRs observed in previous studies may be partly attributable to rehearsal effects. In some of these studies, fully standardized rescripting protocols were employed, where substantial portions of the memory were reactivated prior to the rescripting phase (e.g., Aleksic et al., 2024). Additionally, some studies included extra rehearsal components, such as asking participants to listen to recordings of the intervention between sessions (Ganslmeier et al., 2023). The absence of such rehearsal effects in our study could offer a possible reason for the unexpected findings. Note that we did not employ a standardized, fully pre-scripted ImRs protocol. Instead, participants were instructed to reactivate the memory until they reached its most distressing moment, the hotspot, and then imagine any scenario that would alleviate their distress. As participants differed in which task (presentation, arithmetic task, singing) represented the hotspot for them, the extent to which the original memory was reactivated and subsequently elaborated upon and rehearsed prior to the rescripting phase varied across participants. This variability might have masked potential rehearsal effects, which could account for the positive effects found in previous studies. However, some previous studies reporting positive effects of ImRs on memory accuracy also employed individualized scripts (e.g. Ganslmeier et al., 2022, 2023; Hagenaars & Arntz, 2012), suggesting that the lack of standardization might not be the primary reason for the absence of anticipated positive effects in our study. Notably, the positive effects observed in prior studies were generally small, indicating that the positive impact of ImRs on memory accuracy might be less robust than expected.

The finding that ImRs did not lead to memory impairments, despite containing elements known to increase the probability of such impairments – such as exposure to counterfactual information and imagination – could be attributed to the substantial differences between ImRs and the experimental protocols commonly used in false memory research. The latter have been developed specifically to illustrate the fallibility of memory in light of misinformation and imagination and differ considerably from ImRs as used in our study and in clinical settings. One important distinction that might account for the diverging results is the way in which counterfactual information is presented. For instance, the level of transparency in presenting this information may play a crucial role. It has for example been shown that providing individuals with a warning about the possibility of being presented with misinformation can actually reduce the likelihood of them forming false memories ("warning effect", e.g., Greene et al., 1982; Karanian et al., 2020). In line with ImRs protocols used in clinical practice (e.g. Arntz & Weertman, 1999), participants in our study were transparently informed that changes to their memory will be imagined as part of the intervention. This could have produced a similar protective effect. In addition, it has been shown that warnings are more effective the easier the critical items are to identify in a memory test (Neuschatz et al., 2003). Therefore, the salience of the memory alterations might also play a critical role. In clinically applied ImRs, key aspects of the storyline are changed in order to provide patients with a chance to fulfill unmet needs retroactively and alter the emotional valence of the memory. However, peripheral details, such as the physical appearance of individuals involved, are typically left unchanged, as from a clinical point of view, they hold little relevance with regard to the patient's distress. Accordingly, in our study, participants changed major aspects of their memory rather than peripheral details. In contrast, in typical misinformation studies, participants are neither informed about the memory manipulation nor is the misinformation presented saliently. Instead, false information is presented rather subtly, which clearly deviates from the way memory modifications are introduced in the context of ImRs. In addition, although imagining counterfactual information can lead to memory source confusions (i.e., imagined events being remembered as actually experienced; Johnson et al., 1993; Thomas et al., 2003), this is not always the case. For instance, it has been demonstrated that source monitoring errors due to imagination are less likely the more difficult the image is to create (Finke et al., 1988), when people are aware that they are creating a mental image and when this image is intentionally created (Foley et al., 2006). This is in line with the source monitoring framework, which postulates that increased cognitive operations associated with a memory can serve as cues to correctly attribute them to an internally generated source (Goff & Roediger, 1998; Henkel & Carbuto, 2008; Johnson et al., 1988). Participants in our study did not only intentionally create new images of the TSST scene, but had to perform complex cognitive operations to create these alternative scenarios in their imagination, including imagining new persons entering the scene, what these persons look like, what they sound like, etc. This may have raised participants' awareness of discrepancies between their memory of what happened and what they only imagined, thereby potentially protecting from memory errors.

Taken together, these methodological differences might be important factors in explaining why, so far, consistently different results have been found regarding the memory effects of ImRs vs. experimental paradigms employed in the false memory literature.

Effects of Eye movement desensitization and reprocessing (EMDR)

We expected that EMDR would be associated with *less accurate* memories compared to the other groups. We based this prediction on findings from experimental studies showing that eye movements performed during memory recall reduce memory vividness (Calvillo & Emami, 2019; Kenchel et al., 2020; Lee & Cuijpers, 2013; but see Kevin van Schie & Leer, 2019) and that weaker memories are more susceptible to distortion (Loftus, 2005).

In contrast to this prediction, our findings showed that EMDR did *not* impair memory accuracy, which is at odds with previous studies, in which higher false memory rates had been found after eye movements similar to those used in EMDR (Houben et al., 2018; Houben et al., 2020). One reason for this discrepancy might be that our EMDR intervention was more closely modelled after the clinical application of EMDR than in previous studies, which might have had a protective effect on memory accuracy in our study. For instance, while previous studies often used simple stimulus material for memory induction, such as word lists (Houben et al., 2020), pictures (Leer & Engelhard, 2020) or film clips (Houben et al., 2018), we aimed to induce an emotionally more intense and personally more relevant memory by exposing healthy, but socially anxious, individuals to a social stressor. Given that highly emotional memories are typically the target in psychological treatment, this seems to be a relevant aspect to take into consideration when assessing potential unwanted intervention effects on memory accuracy. In light of the fact that emotional arousal has been found to influence memory performance (e.g., Anderson et al., 2006), the memories examined in our study may have been less susceptible to impairments by the intervention.

Another critical difference between our study and previous research lies in the timing of the intervention. In earlier studies, memory induction, eye movements, and memory tests were all conducted within the same day, often minutes apart (Houben et al., 2018, exp. 1; Leer & Engelhard, 2020). This setup likely led to interference with initial memory consolidation by the eye movements. In clinical practice, however, EMDR typically targets memories that have already undergone consolidation. Therefore, in the present study, we employed a multiple day paradigm where memory induction, intervention and memory test were applied on separate days.

In addition, in previous studies, researchers deliberately introduced misinformation to induce false memories. However, this approach does not reflect the clinical practice of lege artis EMDR, where therapists do not intentionally suggest misinformation (Shapiro, 2017; Lee et al., 2019). Interestingly, in contrast to our findings, a previous study using a similar approach by introducing eye movements after a delay and refraining from presenting misinformation found an increase in both correct responses and false memories after eye movements (Houben et al., 2020, Exp. 2). However, a critical distinction between their study and ours is that their assessment focused on memory for word lists (Deese–Roediger–McDermott paradigm, 1995), whereas we aimed to improve external validity by assessing the effects on more complex memories. The absence of adverse effects on memory accuracy in our study suggests that eye movements within the context of EMDR do not consistently increase susceptibility to memory errors for more complex and personally relevant memories, even when applied after a delay and once the targeted memory has been consolidated.

In addition, to the best of our knowledge, all previous studies have only assessed the effects of isolated eye movements on memory accuracy. However, the EMDR protocol encompasses several elements beyond just eye movements. These include explaining the rationale, explicitly stating that the memory may or may not change during the intervention; elaborating on the original memory by identifying the associated negative image, cognition, emotion, and bodily sensation; and marking the new or alternative cognition and the vividness of the memory at the end of the intervention. These elements might in fact strengthen the original memory through rehearsal while also sensitizing individuals to potential changes in their memory during the intervention, potentially producing a warning effect. Given that we incorporated all these elements in our study, these elements might account for the absence of adverse effects as observed in previous studies.

Apart from these methodological differences, it is important to note that even when employing the same methods to those of previous studies, there has been a series of replication failures regarding both reduction of memory vividness (see Kenchel et al., 2020) and memory impairments (Calvillo & Emami, 2019; Kenchel et al., 2020; van Schie & Leer, 2019). Considering the results of the present study together with these replication challenges, it appears that there is currently no strong evidence that EMDR impairs memory for complex, emotionally relevant events in the absence of external suggestive influences.

Effects of Imaginal Exposure (IE)

We expected IE to be associated with better memory accuracy compared to EMDR and NIC. However, our findings did not support this assumption. While IE did not impair memory accuracy, it also did not enhance it as anticipated. This outcome is surprising, given that participants in the IE group intensely rehearsed the entire memory during the intervention. We expected that this would improve memory recall due to rehearsal effects (Roediger & Butler, 2011), and previous studies had indeed reported improved memory performance after IE (Ganslmeier et al., 2023; Hagenaars & Arntz, 2012; Houben et al., 2018; Siegesleitner et al., 2019).

One reason why we did not find this beneficial effect in the present study might be the dose of rehearsal. Although IE involved extensive rehearsal, all intervention groups in our study included some degree of memory rehearsal. This might have minimized differences between groups, making it harder to detect the specific beneficial effects of IE. However, as IE was not associated with better memory accuracy than NIC, which did not involve any memory rehearsal, the lack of findings can not be solely attributed to the presence of rehearsal effects in all intervention groups.

Moreover, the single session of IE provided in our study may not have been sufficient to produce notable improvements. However, previous studies reporting improved memory performance after IE also included single intervention sessions which were often even shorter compared to the present study (but see Ganslmeier et al., 2023, who incorporated additional rehearsal by asking participants to listen to recordings of the intervention between sessions).

Another explanation might be that we assessed memory for an experimentally induced and relatively recent event. Memory accuracy for such recent and controlled events might already be high, leaving little room for improvement. This could have resulted in a ceiling effect, where the initial memory was so strong that further enhancement was difficult to achieve. This assumption is supported by our attempt to enhance the emotional impact of the event compared to previous studies, which mostly used film clips for memory induction. We exposed socially anxious participants to a social stressor, creating a more emotional and personally meaningful event. Consequently, memory for this type of event might have been better than for the film clips used in other studies, therefore leaving less room for improvement.

General discussion

Taken together, the findings of the present study do not indicate that EMDR, ImRs, or IE impair memory accuracy. The observed reduction of intrusion distress and intrusion load in EMDR and IE, without adverse effects on memory accuracy, supports the notion that voluntary and involuntary memories can be separately and selectively targeted by psychological interventions (e.g., Golkar et al., 2017; Lau-Zhu et al., 2019). However, it is noteworthy that only EMDR, but not ImRs or IE, resulted in a greater reduction in the number of intrusive memories compared to NIC. This outcome might be attributed to a floor effect, given that only a small number of intrusive memories were initially induced by the TSST and there was a rapid decline in intrusive memories across all groups. Despite attempts to enhance the aversiveness of the TSST, such as exposing socially anxious participants to it, the stressor may still have been too mild to induce a sufficient number of intrusive memories to adequately assess intervention effectiveness.

Establishing whether these interventions have robust dissociative effects on voluntary versus involuntary memory across different memory measures could be valuable in better understanding their mechanisms. For instance, Brewin's (2014) dual representation theory suggests that trauma-focused interventions facilitate the integration of disintegrated memory representations, resulting in both improved deliberate recall of the traumatic event and reduced involuntary recall. This contrasts with concerns about potential adverse effects of trauma-focused interventions on memory accuracy. Our study design may not have been suited to assess these beneficial effects due to the mild nature of the stressor used for memory induction.

Future studies should therefore consider using different paradigms or assessing intervention effects on autobiographical memories to evaluate intervention effects on more complex and emotionally charged memories.

Strengths and limitations

Our study has a number of important strengths. First, our study is the first to directly compare the effects of EMDR, IE and ImRs on memory accuracy. Second, in contrast to most previous studies, we used a multiple-day paradigm which allowed us to assess intervention effects on consolidated memories which are typically the target of psychological interventions. Third, by exposing socially anxious participants to a social stressor, we induced a more complex, personally relevant and emotionally charged memory than earlier studies using film clips, pictures or word lists to assess intervention effects on memory accuracy. Fourth, we assessed the effects of EMDR using an adapted version of Shapiro's (2001) eight-phase EMDR protocol instead of assessing the effects of isolated eye-movements only. Finally, in line with previous studies from our group (Aleksic et al., 2024; Ganslmeier et al., 2022; 2023), we designed our items to assess memory accuracy with a particular emphasis on information that holds practical relevance, especially within the legal context, including aspects such as identifying features of the perpetrators and the chronology of events.

Despite these strengths, the results of the present study must also be interpreted in light of some limitations. First, the generalizability of our findings is limited, as we did not evaluate the intervention effects in a patient population or on real autobiographical or traumatic memories. Instead, our study involved a healthy sample and focused on experimentally induced memories. Using the TSST for memory induction ensured experimental control over the memory content, which was crucial for the purpose of our study. However, EMDR, IE and ImRs are typically used in the context of traumatic events, which of course are not comparable to the TSST regarding the aversiveness of the experience and the associated arousal, both factors that might strengthen the original memory and therefore reduce the susceptibility to memory impairments (Loftus et al., 2005). In addition, clinical populations might be more susceptible to memory errors given that factors such as trait dissociation (e.g., Clancy et al., 2000), arousal (Corson & Verrier, 2007), and depression (e.g., Brennen et al., 2007) have been found do be associated with susceptibility (see Loftus & Davis, 2006 for a review). The relative mildness of the stressor used in our study might also explain why we could not induce a sufficient number of intrusive memories to investigate intervention effects on intrusion reduction. Although this was not the focus of the present study, it appears crucial to establish whether memory accuracy would also remain unimpaired after ImRs and IE when they show the intended reduction of intrusive memories. This seems particularly relevant for ImRs since we did not observe any intervention effects of ImRs while we did at least observe a reduction in intrusion distress and intrusion load after EMDR and IE.

Second, while we extended the time intervals between memory induction, intervention, and memory test compared to previous studies, these periods are still not equivalent to clinical practice, where trauma-focused interventions address memories of events that often took place months or years ago. We can therefore not exclude the possibility that different memory effects of ImRs, EMDR and IE would be observed if applied after a longer time interval. This appears particularly important in light of findings that, as time passes, memories weaken and become more susceptible to distortion (Loftus, 2005). In accordance with the source monitoring framework (Johnson, 2006), a longer interval between memory induction and intervention might therefore increase the risk of memory distortion. Future studies should therefore consider introducing even longer time intervals to assess intervention effects on older memories.

Third, the generalizability of the intervention effects observed in our study may be further constrained by the fact that we used experimental and stripped-down intervention protocols. For instance, given that we conducted our assessments in a healthy sample and worked with experimentally induced memories rather than childhood trauma memories, certain elements such as the switch between adult and child perspectives in the ImRs protocol were omitted. Although we incorporated elements known to increase the risk of memory impairments—such as imagery-based memory reactivation in all intervention conditions, modifications of the script in ImRs, and eye movements in EMDR—we cannot exclude the possibility that different outcomes might have been observed if the interventions had been conducted within the context of real clinical treatment.

Fourth, as participants received half-standardized interventions, we did not have full control over the contents imagined during the interventions. For example, participants receiving ImRs decided individually how exactly they changed the script to reduce the associated distress. Similarly, participants receiving EMDR identified their individual most distressing cognition and image associated with the original memory and formulated their own individual positive target cognitions. We could therefore only assess whether memories of the original event details were less accurate after having received an intervention compared to no intervention. However, we could not assess whether counterfactual information that might have been imagined during the interventions, either intentionally introduced as part of the rescripting phase in ImRs or spontaneously occurring in the absence of externally provided misinformation, was later falsely remembered as part of the original event. Future studies might consider to additionally investigate whether counterfactual details introduced during the interventions are later erroneously incorporated into memory reports (e.g., Reineck et al., in prep.).

Fifth, our assessment of memory accuracy relied solely on a cued recall task. Considering that trauma survivors often have to give detailed verbal statements or identify offenders in line-ups during criminal proceedings, the inclusion of different memory measures, such as a free recall or a stimulus discrimination task in addition to a cued recall task, might increase the informative value and external validity of the study. Moreover, investigating intervention effects on different memory measures is crucial given that different memory tasks may engage different cognitive processes and therefore yield different results. For instance, previous studies using a stimulus discrimination task have demonstrated distinct effects of eye movements on discrimination speed versus discrimination accuracy (Leer et al., 2017; van den Hout et al., 2013). Additionally, findings from cued recall tasks have been found to differ from free recall tasks in some studies (e.g., Malloggi et al., 2022). Although earlier studies on ImRs using free recall tasks found consistent results across both memory recognition and free recall (Ganslmeier et al., 2022, 2023), it remains unclear whether our findings would replicate with different memory measures.

Finally, we only assessed the effects of one single intervention session, which limits our ability to draw conclusions about the memory effects of repeated sessions which are commonly employed in clinical practice. It is worth noting that repeated memory retrieval not only has been demonstrated to enhance memory (Roediger & Butler, 2011), but also susceptibility to memory impairments in the context of misinformation (Heaps & Nash, 2001; Henkel, 2004). Additionally, the misinformation effect hast been found to increase with repeated presentation of misinformation (Foster et al., 2012). Given these findings, it is crucial to evaluate the effects of repeated intervention sessions, especially for ImRs, where some form of misinformation is regularly introduced during the rescripting phase. However, it is important to note that previous studies have not observed memory impairments after ImRs, even when participants were repeatedly exposed to recordings of the intervention (Ganslmeier et al., 2022; 2023).

Implications

Our findings, together with those of previous studies, challenge the concern that trauma-focused interventions such as EMDR, ImRs, and IE inherently lead to memory distortion. This is particularly relevant for trauma survivors who need to testify in legal cases, where the accuracy of their memory is crucial for credibility assessment in court (Gasch, 2018; Schemmel & Volbert, 2021). This concern often creates a dilemma for patients, forcing them to choose between prioritizing their mental health by seeking psychological treatment or maintaining their credibility as witnesses (Bublitz, 2020).

While our findings are encouraging from a clinical point of view, the potential for suggestive processes within trauma-focused treatment can not be entirely dismissed based on our findings. It is important to acknowledge that psychological treatment might become a critical setting for potential memory distortions under certain circumstances. For instance, the risk of memory distortion is particularly high when individuals are uncertain about their own memories (Gabbert et al., 2003), especially if misinformation comes from a credible and trusted authority figure (Pena et al., 2017). Patients experiencing memory gaps or seeking explanations for their distress might therefore be particularly vulnerable to suggestive influences from therapists. This can be especially critical in cases where therapists actively search for "repressed" memories based on observed symptoms, even if there was no prior memory of trauma before treatment. However, it is important to recognize that suggestive processes and social pressure to accept misinformation can also occur in interactions with professionals outside the therapeutic context, such as police officers, lawyers, and even family members and friends. Therefore, understanding the conditions under which the therapeutic setting might become particularly risky for memory distortion is crucial both to mitigate the risk of memory distortion and to ensure patients receive appropriate and timely treatment.

Given the limited number of studies to date, there is a high need for systematic research to identify factors that might increase the risk of memory distortion through trauma-focused interventions. Findings from these studies can help sensitize psychological professionals and professionals in the legal field to potential risk constellations and inform training and treatment guidelines.

Conclusion

In sum, our findings provide a valuable contribution to the ongoing debate on whether trauma-focused psychological interventions impair the accuracy of memories targeted in treatment. Our study expands earlier research by comparing the effects of three commonly used interventions: EMDR, IE, and ImRs. Additionally, we adapted the methods used in previous studies to better reflect the conditions typically found in psychological treatment, which may influence the memory effects of these interventions. Our data indicate that none of the interventions causes impairments in the accuracy of memories for complex events, even when applied after a time delay. Although these findings are very reassuring from a clinical perspective, future research is needed to better understand potential risk conditions that could cause these interventions to distort memory of factual events.

Transparency

Conflict of interest

MA, AK TE, and LW have no conflicts of interest to disclose.

Author contributions

Conceptualization: A. Kunze, M. Aleksic, L. Wolkenstein, T. Ehring; Methodology: A. Kunze, M. Aleksic, L. Wolkenstein, T. Ehring; Software (Online-Platform for experimental design): M. Aleksic; Investigation: M. Aleksic;

Project administration: M. Aleksic; Formal analysis: M. Aleksic; Writing – original draft: M. Aleksic; Writing – review and editing: M. Aleksic, Wolkenstein, T. Ehring; Visualization: M. Aleksic; Supervision: L. Wolkenstein, T. Ehring, A. Kunze. All authors approved the final version of the manuscript for submission.

Declaration of generative AI in scientific writing

During the preparation of this work the authors used ChatGPT and DeepL for proofreading in order to improve readability and language. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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Preregistration

The hypotheses, study design and analysis plan of this study were preregistered at the Open Science Framework (https://osf.io/7sveq/).

Data Availability Statement

Anonymized data, codes and study materials have been made publicly available via the Open Science Framework and can be accessed at https://osf.io/h3c7w/. The design and analysis plan for the experiment were preregistered at OSF and can be accessed at https://osf.io/7sveq.

Ethical approval

The study was carried out in accordance with the provisions of the World Medical Association Declaration of Helsinki and approved by the local Research Ethics Committee of the Department of Psychology at LMU Munich (17_Ehring_b). All participants provided written informed consent.

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References Study I

Aleksic, M., Reineck, A., Ehring, T., & Wolkenstein, L. (2024). When does imagery rescripting become a double-edged sword? - Investigating the risk of memory distortion through imagery rescripting in an online Trauma film study. *Behaviour Research and Therapy*, *174*, 104495. https://doi.org/10.1016/j.brat.2024.104495

Anderson, A. K., Yamaguchi, Y., Grabski, W., & Lacka, D. (2006). Emotional memories are not all created equal: Evidence for selective memory enhancement. *Learning and Memory*, *13*(6), 711–718. https://doi.org/10.1101/lm.388906

Arntz, A & Weertman, A. (1999). Arntz, A., & Weertman, A. (1999). Treatment of childhood memories: Theory and practice. *Behaviour Reserch and Therapy*, *37*, 715–740.

Arntz, A. (2012). Imagery Rescripting as a Therapeutic Technique: Review of Clinical Trials, Basic Studies, and Research Agenda. *Journal of Experimental Psychopathology*, *3*(2), 189–208. https://doi.org/10.5127/jep.024211

Boterhoven De Haan, K. L., Lee, C. W., Fassbinder, E., Van Es, S. M., Menninga, S., Meewisse, M. L., Rijkeboer, M., Kousemaker, M., & Arntz, A. (2020). Imagery rescripting and eye movement desensitisation and reprocessing as treatment for adults with post-traumatic stress disorder from childhood trauma: Randomised clinical trial. *British Journal of Psychiatry*, *217*(5), 609–615. https://doi.org/10.1192/bjp.2020.158

Bradley, M. M., & Lang, P. J. (1994). Measuring emotion: The self-assessment manikin and the semantic differential. *Journal of Behavior Therapy and Experimental Psychiatry*, 25(1), 49–59.

Brennen, T., Dybdahl, R., & Kapidžić, A. (2007). Trauma-related and neutral false memories in war-induced Posttraumatic Stress Disorder. *Consciousness and Cognition*, *16*(4), 877–885. https://doi.org/10.1016/j.concog.2006.06.012

Brewer, N., & Burke, A. (2002). Effects of testimonial inconsistencies and witness group identity on mock-juror judgments. *Law and Human Behavior*, *26*(3), 353–364. https://doi.org/10.1023/a:1015380522722

Brewin, C. R. (2014). Episodic memory, perceptual memory, and their interaction: Foundations for a theory of posttraumatic stress disorder. *Psychological Bulletin*, *140*(1), 69–97. https://doi.org/10.1037/a0033722

Brewin, C. R., & Andrews, B. (2017). Creating Memories for False Autobiographical Events in Childhood: A Systematic Review. *Applied Cognitive Psychology*, *31*(1), 2–23. https://doi.org/10.1002/acp.3220

Brewin, C. R., Dalgleish, T., & Joseph, S. (1996). A dual representation theory of Posttraumatic Stress Disorder. *Psychological Review*, *103*(4), 670–686.

Brewin, C. R., Gregory, J. D., Lipton, M., & Burgess, N. (2010). Intrusive Images in Psychological Disorders: Characteristics, Neural Mechanisms, and Treatment Implications. *Psychological Review*, *117*(1), 210–232. https://doi.org/10.1037/a0018113

Bublitz, C. (2020). Health or credibility? Overcoming the dilemma of trauma therapy. *Ethik in Der Medizin*, 65–83. https://doi.org/10.1007/s00481-019-00560-3

Busey, T. A., Tunnicliff, J., Loftus, G. R., & Loftus, E. F. (2000). Accounts of the confidence-accuracy relation in recognition memory. *Psychonomic Bulletin and Review*, *7*(1), 26–48. https://doi.org/10.3758/BF03210724

Calvillo, D. P., & Emami, A. S. (2019). Do lateral eye movements increase susceptibility to misinformation? A registered replication. *Psychonomic bulletin & review, 26*, 1905-1910.

Clancy, S. A., Schacter, D. L., McNally, R. J., & Pitman, R. K. (2000). False recognition in women reporting recovered memories of sexual abuse. *Psychological Science*, *11*(1), 26–31. https://doi.org/10.1111/1467-9280.00210

Cooper, A. A., Clifton, E. G., & Feeny, N. C. (2017). An Empirical Review of Potential Mediators and Mechanisms of Prolonged Exposure Therapy. *Clinical Psychology Review*, *56*, 106–121. https://doi.org/doi:10.1016/j.cpr.2017.07.003

Corson, Y., & Verrier, N. (2007). Emotions and False Memories. *Psychological Science*, *18*(3), 208–211.

Craske, M. G., Treanor, M., Conway, C. C., Zbozinek, T., & Vervliet, B. (2014). Maximizing exposure therapy: An inhibitory learning approach. *Behaviour Research and Therapy*, *58*, 10–23. https://doi.org/10.1016/j.brat.2014.04.006

Davis, D., & Loftus, E. F. (2020). Recovered memories and false memories. *New oxford textbook of psychiatry*, 884-893.

Dibbets, P., & Arntz, A. (2016). Imagery rescripting: Is incorporation of the most aversive scenes necessary? *Memory*, *24*(5), 683–695. https://doi.org/10.1080/09658211.2015.1043307

Duchesne, A., Tessera, E., Dedovic, K., Engert, V., & Pruessner, J. C. (2012). Effects of panel sex composition on the physiological stress responses to psychosocial stress in healthy young men and women. *Biological Psychology*, *89*(1), 99–106. https://doi.org/10.1016/j.biopsycho.2011.09.009

Finke, R. A., Johnson, M. K., & Shyi, G. C. W. (1988). Memory confusions for real and imagined completions of symmetrical visual patterns. *Memory & Cognition*, *16*(2), 133–137. https://doi.org/10.3758/BF03213481

Foa, E. B., Dancu, C. V., Hembree, E. A., Jaycox, L. H., Meadows, E. A., & Street, G. P. (1999). A comparison of exposure therapy, stress inoculation training, and their combination for reducing posttraumatic stress disorder in female assault victims. *Journal of Consulting and Clinical Psychology*, *67*(2), 194–200. https://doi.org/10.1037//0022-006x.67.2.194

Foa, E. B., Steketee, G., & Rothbaum, B. O. (1989). Behavioral/cognitive conceptualizations of post-traumatic stress disorder. *Behavior Therapy*, *20*(2), 155–176.

Foley, M. A., Wozniak, K. H., & Gillum, A. (2006). Imagination and false memory inductions: Investigating the role of process, content and source of imaginations. *Applied Cognitive Psychology*, *20*(9), 1119–1141. https://doi.org/10.1002/acp.1265

Foster, J. L., Huthwaite, T., Yesberg, J. A., Garry, M., & Loftus, E. F. (2012). Repetition, not number of sources, increases both susceptibility to misinformation and confidence in the accuracy of eyewitnesses. *Acta Psychologica*, *139*(2), 320–326.

https://doi.org/10.1016/j.actpsy.2011.12.004

Freund, I. M., Peters, J., Kindt, M., & Visser, R. M. (2023). Emotional memory in the lab: Using the Trier Social Stress Test to induce a sensory-rich and personally meaningful episodic experience. *Psychoneuroendocrinology, 148*, 105971.

Gabbert, F., Memon, A., & Allan, K. (2003). Memory conformity: Can eyewitnesses influence each other's memories for an event? *Applied Cognitive Psychology, 17*(5), 533–543. https://doi.org/10.1002/acp.885

Ganslmeier, M., Ehring, T., & Wolkenstein, L. (2023). Effects of imagery rescripting and imaginal exposure on voluntary memory. *Behaviour Research and Therapy, 170*, 104409.

Ganslmeier, M., Kunze, A. E., Ehring, T., & Wolkenstein, L. (2022). The dilemma of trauma-focused therapy: effects of imagery rescripting on voluntary memory. *Psychological Research, 87* (5), 1616-1631.

Garry, M., Manning, C. G., Loftus, E. F., & Sherman, S. J. (1996). Imagination inflation: Imagining a childhood event inflates confidence that it occurred. *Psychonomic Bulletin and Review, 3*(2), 208–214. https://doi.org/10.3758/BF03212420

Gasch, U. (2018). Psychotherapie vor Abschluss der Beweisaufnahme im Strafverfahren? Traumatherapie als potenzielle Fehlerquelle bei der Tatsachenfeststellung. *Kriminalistik*, 12/2018, 734-738.

Goff, L. M., & Roediger, H. L. (1998). Imagination inflation for action events: Repeated imaginings lead to illusory recollections. *Memory and Cognition*, *26*(1), 20–33. https://doi.org/10.3758/BF03211367

Golkar, A., Tjaden, C., & Kindt, M. (2017). Vicarious extinction learning during reconsolidation neutralizes fear memory. *Behaviour research and therapy, 92*, 87-93.

Greene, E., Flynn, M. S., & Loftus, E. F. (1982). Inducing resistance to misleading information. *Journal of Verbal Learning and Verbal Behavior, 21*(2), 207–219. https://doi.org/10.1016/S0022-5371(82)90571-0

Hagenaars, M. A., & Arntz, A. (2012). Reduced intrusion development after post-trauma imagery rescripting; An experimental study. *Journal of Behavior Therapy and Experimental Psychiatry*, *43*(2), 808–814. https://doi.org/10.1016/j.jbtep.2011.09.005

Heaps, C. M., & Nash, M. (2001). Comparing Recollective Experience in True and False Autobiographical Memories. *Journal of Experimental Psychology: Learning Memory and Cognition*, *27*(4), 920–930. https://doi.org/10.1037/0278-7393.27.4.920

Henkel, L. A. (2004). Erroneous memories arising from repeated attempts to remember. *Journal of Memory and Language, 50*(1), 26–46. https://doi.org/10.1016/j.jml.2003.08.001

Henkel, L. A., & Carbuto, M. (2008). Remembering what we did: How source misattributions arise from verbalization, mental imagery, and pictures. *Applied memory*, 213-234.

Hermanutz, M., & Schröder, J. (2015). Leitfaden zur Vernehmung von Zeugen und Beschuldigten mit Vernehmungskarten. *Hochschule Hannover, 148*, 148–162.

Holmes, E. A., & Bourne, C. (2008). Inducing and modulating intrusive emotional memories: A review of the trauma film paradigm. *Acta Psychologica*, *127*(3), 553–566. https://doi.org/10.1016/j.actpsy.2007.11.002

Holmes, E. A., Brewin, C. R., & Hennessy, R. G. (2004). Trauma Films, Information Processing, and Intrusive Memory Development. *Journal of Experimental Psychology: General*, *133*(1), 3–22. https://doi.org/10.1037/0096-3445.133.1.3

Houben, S. T. L., Otgaar, H., Roelofs, J., & Merckelbach, H. (2018). Lateral Eye Movements Increase False Memory Rates. *Clinical Psychological Science*, *6*(4), 610–616. https://doi.org/10.1177/2167702618757658

Houben, S. T. L., Otgaar, H., Roelofs, J., Smeets, T., & Merckelbach, H. (2020). Increases of correct memories and spontaneous false memories due to eye movements when memories are retrieved after a time delay. *Behaviour Research and Therapy*, *125*, 103546. https://doi.org/10.1016/j.brat.2019.103546

James, E. L., Bonsall, M. B., Hoppitt, L., Tunbridge, E. M., Geddes, J. R., Milton, A. L., & Holmes, E. A. (2015). Computer Game Play Reduces Intrusive Memories of Experimental Trauma via Reconsolidation-Update Mechanisms. *Psychological Science*, *26*(8), 1201–1215. https://doi.org/10.1177/0956797615583071

Johnson, M. K. (2006). Memory and reality. *American Psychologist*, *61*(8), 760–771. https://doi.org/10.1037/0003-066X.61.8.760

Johnson, M. K., Foley, M. A., Suengas, A. G., & Raye, C. L. (1988). Phenomenal Characteristics of Memories for Perceived and Imagined Autobiographical Events. *Journal of Experimental Psychology: General*, *117*(4), 371–376. https://doi.org/10.1037/0096-3445.117.4.371

Johnson, M. K., Hashtroudi, S., & Lindsay, D. S. (1993). Source monitoring. *Psychological bulletin*, *114*(1), 3.

Karanian, J. M., Rabb, N., Wulff, A. N., Torrance, M. G., Thomas, A. K., & Race, E. (2020). Protecting memory from misinformation: Warnings modulate cortical reinstatement during memory retrieval. *Proceedings of the National Academy of Sciences of the United States of America*, *117*(37), 22771–22779. https://doi.org/10.1073/pnas.2008595117

Kavanagh, D. J., Freese, S., Andrade, J., & May, J. (2001). Effects of visuospatial tasks on desensitization to emotive memories. *British Journal of Clinical Psychology*, *40*(3), 267–280. https://doi.org/10.1348/014466501163689

Kenchel, J. M., Domagalski, K., Butler, B. J., & Loftus, E. F. (2022). The messy landscape of eye movements and false memories. *Memory*, *30*(6), 678-685.

Kindt, M., & Elsey, J. W. (2023). A paradigm shift in the treatment of emotional memory disorders: lessons from basic science. *Brain research bulletin*, *192*, 168-174.

Kindt, M., & Soeter, M. (n.d.). is time and sleep dependent. *Nature Communications*, *2018*. https://doi.org/10.1038/s41467-018-03659-1

Kirschbaum, C., Pirke, K.-M., & Hellhammer, D. H. (1993). The “Trier Social Stress Test” - A Tool for Investigating Psychobiological Stress Responses in a Laboratory Setting. *Neuropsychobiology*, *28*, 76–81. https://doi.org/10.1159/000119004

Krohne, H. W., Egloff, B., Kohlmann, C. W., & Tausch, A. (1996). Untersuchungen mit einer deutschen Version der Positive and Negative Affect Schedule (PANAS) [Investi- gations with a German version of the Positive and Negative Affect Schedule (PANAS)]. *Diagnostica*, 42, 139-156.

Kunze, A. E., Arntz, A., Morina, N., Kindt, M., & Lancee, J. (2017). Efficacy of imagery rescripting and imaginal exposure for nightmares: A randomized wait-list controlled trial. *Behaviour Research and Therapy, 97*, 14–25. https://doi.org/10.1016/j.brat.2017.06.005

Laux, L., Glanzmann, P., Schaffner, P., & Spielberger, C. (1981). *Das State-Trait-Angstinventar.* Theoretische Grundlagen und Handanweisung. Weinheim: Beltz Test.

Lau-Zhu, A., Henson, R. N., & Holmes, E. A. (2019). Intrusive memories and voluntary memory of a trauma film: Differential effects of a cognitive interference task after encoding. *Journal of Experimental Psychology: General, 148*(12), 2154.

Leding, J. K., & Antonio, L. (2019). Need for cognition and discrepancy detection in the misinformation effect. *Journal of Cognitive Psychology*, *31*(4), 409–415. https://doi.org/10.1080/20445911.2019.1626400

Lee, C. W., & Cuijpers, P. (2013). A meta-analysis of the contribution of eye movements in processing emotional memories. *Journal of Behavior Therapy and Experimental Psychiatry*, *44*(2), 231–239. https://doi.org/10.1016/j.jbtep.2012.11.001

Lee, C. W., de Jongh, A., & Hase, M. (2019). Lateral Eye Movements, EMDR, and Memory Changes: A Critical Commentary on Houben et al. (2018). *Clinical Psychological Science, 7*(3), 403–404. https://doi.org/10.1177/2167702619830395

Leer, A., & Engelhard, I. M. (2020). Side effects of induced lateral eye movements during aversive ideation. *Journal of behavior therapy and experimental psychiatry, 68*, 101566.

Leer, A., Engelhard, I. M., Lenaert, B., Struyf, D., Vervliet, B., & Hermans, D. (2017). Eye movement during recall reduces objective memory performance: An extended replication. *Behaviour Research and Therapy*, *92*, 94–105. https://doi.org/10.1016/j.brat.2017.03.002

Leer, A., Engelhard, I. M., & Van Den Hout, M. A. (2014). How eye movements in EMDR work: Changes in memory vividness and emotionality. *Journal of Behavior Therapy and Experimental Psychiatry*, *45*(3), 396–401. https://doi.org/10.1016/j.jbtep.2014.04.004

Lindsay, D. S., & Johnson, M. K. (2000). False memories and the source monitoring framework: Reply to Reyna and Lloyd (1997). *Learning and Individual Differences*, *12*(2), 145–161. https://doi.org/10.1016/S1041-6080(01)00035-8

Loftus, E. F. (1992). When A Lie Becomes Memory’s Truth: Memory Distortion After Exposure to Misinformation. *Current Directions in Psychological Science*, *1*(4), 121–123. https://doi.org/10.1111/1467-8721.ep10769035

Loftus, E. F. (1997). Creating false memories. *Scientific American, 277*(3), 70-75.

Loftus, E. F. (2005). Planting misinformation in the human mind: A 30-year investigation of the malleability of memory. *Learning and Memory*, *12*(4), 361–366. https://doi.org/10.1101/lm.94705

Loftus, E. F., & Davis, D. (2006). Recovered memories. *Annual Review of Clinical Psychology*, *2,* 469–498. https://doi.org/10.1146/annurev.clinpsy.2.022305.095315

Loftus, E. F., & Klemfuss, J. Z. (2024). Misinformation–past, present, and future. *Psychology, Crime & Law,* 1-7. https://doi.org/10.1080/1068316X.2023.2219813

Lyle, K. B., & Johnson, M. K. (2007). Source misattributions may increase the accuracy of source judgments. *Memory and Cognition*, *35*(5), 1024–1033. https://doi.org/10.3758/BF03193475

Malloggi, S., Conte, F., De Rosa, O., Cellini, N., Di Iorio, I., Ficca, G., & Giganti, F. (2022). False recalls, but not false recognitions, at the DRM paradigm are increased in subjects reporting insomnia symptoms: An online study. *Sleep Medicine*, *100*, 347–353. https://doi.org/10.1016/j.sleep.2022.09.005

Mattick, R. P., & Clarke, J. C. (1998). Development and validation of measures of social phobia scrutiny fear and social interaction anxiety. *Behaviour Research and Therapy*, *36*(4), 455–470. https://doi.org/10.1016/S0005-7967(97)10031-6

Mazzoni, G., & Memon, A. (2003). Imagination can create false autobiographical memories. *Psychological Science*, *14*(2), 186–188. https://doi.org/10.1046/j.1432-1327.2000.01821.x

Michael, T., Ehlers, A., Halligan, S. L., & Clark, D. M. (2005). Unwanted memories of assault: What intrusion characteristics are associated with PTSD? *Behaviour Research and Therapy*, *43*(5), 613–628. https://doi.org/10.1016/j.brat.2004.04.006

Morina, N., Lancee, J., & Arntz, A. (2017). Imagery rescripting as a clinical intervention for aversive memories: A meta-analysis. *Journal of Behavior Therapy and Experimental Psychiatry*, *55*, 6–15. https://doi.org/10.1016/j.jbtep.2016.11.003

Nader, K., Schafe, G. E., & LeDoux, J. E. (2000). The labile nature of consolidation theory. *Nature reviews neuroscience, 1*(3), 216-219.

Neuschatz, J. S., Benoit, G. E., & Payne, D. G. (2003). Effective Warnings in the Deese-Roediger-McDermott False-Memory Paradigm: The Role of Identifiability. *Journal of Experimental Psychology: Learning Memory and Cognition*, *29*(1), 35–41. https://doi.org/10.1037/0278-7393.29.1.35

Odinot, G., Wolters, G., & van Giezen, A. (2013). Accuracy, confidence and consistency in repeated recall of events. *Psychology, Crime and Law*, *19*(7), 629–642. https://doi.org/10.1080/1068316X.2012.660152

Otgaar, H., Houben, S. T. L., Rassin, E., & Merckelbach, H. (2021). Memory and eye movement desensitization and reprocessing therapy: a potentially risky combination in the courtroom. *Memory*, *29*(9), 1254–1262. https://doi.org/10.1080/09658211.2021.1966043

Pena, M. M., Klemfuss, J. Z., Loftus, E. F., & Mindthoff, A. (2017). The effects of exposure to differing amounts of misinformation and source credibility perception on source monitoring and memory accuracy. *Psychology of Consciousness: Theory Research, and Practice*, *4*(4), 337–347. https://doi.org/10.1037/cns0000137

Powers, M. B., Halpern, J. M., Ferenschak, M. P., Gillihan, S. J., & Foa, E. B. (2010). A meta-analytic review of prolonged exposure for posttraumatic stress disorder. *Clinical*

Psychology Review, *30*(6), 635–641. https://doi.org/10.1016/j.cpr.2010.04.007

R Core Team (2023). R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. <https://www.R-project.org/>.

Roediger, H. L., & Butler, A. C. (2011). The critical role of retrieval practice in long-term retention. *Trends in Cognitive Sciences*, *15*(1), 20–27. https://doi.org/10.1016/j.tics.2010.09.003

Roediger, H. L., & McDermott, K. B. (1995). Creating False Memories: Remembering Words Not Presented in Lists. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *21*(4), 803–814. https://doi.org/10.1037/0278-7393.21.4.803

Roediger, H. L., Wixted, J. H., & Andrew Desoto, K. (2012). The Curious Complexity between Confidence and Accuracy in Reports from Memory. *Memory and Law*, 84–118. https://doi.org/10.1093/acprof:oso/9780199920754.003.0004

Roniger, A., Späth, C., Schweiger, U., & Klein, J. P. (2015). A psychometric evaluation of the German version of the quick inventory of depressive symptomatology (QIDS-SR16) in outpatients with depression. *Fortschritte Der Neurologie· Psychiatrie, 83*(12), e17-e22.

Rush, A. J., Gullion, C. M., Basco, M. R., Jarrett, R. B., & Trivedi, M. H. (1996). The inventory of depressive symptomatology (IDS): Psychometric properties. *Psychological Medicine*, *26*(3), 477–486. https://doi.org/10.1017/s0033291700035558

Schemmel, J., & Volbert, R. (2021). Therapie oder Glaubhaftigkeit?. *Die Erhebung und Bewertung von Zeugenaussagen im Strafprozess.*

Sevenster, D., Beckers, T., & Kindt, M. (2013). Prediction error governs pharmacologically induced amnesia for learned fear. *Science*, *339*(6121), 830–833. https://doi.org/10.1126/science.1231357

Shapiro, F. (2017). E*ye movement desensitization and reprocessing (EMDR) therapy: Basic principles, protocols, and procedures.* Guilford Publications.

Siegesleitner, M., Strohm, M., Wittekind, C. E., Ehring, T., & Kunze, A. E. (2019). Effects of imagery rescripting on consolidated memories of an aversive film. *Journal of Behavior Therapy and Experimental Psychiatry, 62*, 22-29.

Spielberger, C. D., Gorsuch, R. L., & Lushene, R. (1970). *Manual for the State-Trait Anxiety Inventory.* Palo Alto, CA: Consulting Psychologists Press

Stanek, M. L., Boaz, K. M., Cordes, C. N., Niese, T. D., Long, K. E., Risner, M. S., ... & Zoladz, P. R. (2024). Social evaluative stress enhances central detail memory, reduces false memory, and results in intrusive memories that last for days. *Neurobiology of Learning and Memory, 209*, 107906.

Stangier, U., Heidenreich, T., Berardi, A., Golbs, U., & Hoyer, J. (1999). Die erfassung sozialer phobie durch social interaction anxiety scale (SIAS) und die social phobia scale (SPS). *Zeitschrift für klinische Psychologie*.

Stark, C. E. L., Okado, Y., & Loftus, E. F. (2010). Imaging the reconstruction of true and false memories using sensory reactivation and the misinformation paradigms. *Learning and Memory*, *17*(10), 485–488. https://doi.org/10.1101/lm.1845710

Steil, R., & Ehlers, A. (2000). Dysfunctional meaning of posttraumatic intrusions in chronic PTSD. *Behaviour Research and Therapy*, *38*(6), 537–558. https://doi.org/10.1016/S0005-7967(99)00069-8

Strohm, M., Siegesleitner, M., Kunze, A. E., Werner, G. G., Ehring, T., & Wittekind, C. E. (2021). Psychological and Physiological Effects of Imagery Rescripting for Aversive Autobiographical Memories. *Cognitive Therapy and Research*, *45*(6), 1093–1104. https://doi.org/10.1007/s10608-021-10233-5

Thomas, A. K., Bulevich, J. B., & Loftus, E. F. (2003). Exploring the role of repetition and sensory elaboration in the imagination inflation effect. *Memory and Cognition*, *31*(4), 630–640. https://doi.org/10.3758/BF03196103

Thomas, A. K., & Loftus, E. F. (2002). Creating bizarre false memories through imagination. *Memory and Cognition*, *30*(3), 423–431. https://doi.org/10.3758/BF03194942

Tousignant, J. P., Hall, D., & Loftus, E. F. (1986). Discrepancy detection and vulnerability to misleading postevent information. *Memory & Cognition*, *14*(4), 329–338. https://doi.org/10.3758/BF03202511

van den Hout, M. A., Bartelski, N., & Engelhard, I. M. (2013). On EMDR: Eye movements during retrieval reduce subjective vividness and objective memory accessibility during future recall. *Cognition and Emotion*, *27*(1), 177–183. https://doi.org/10.1080/02699931.2012.691087

van den Hout, M. A., & Engelhard, I. M. (2012). How does EMDR work? *Journal of Experimental Psychopathology*, *3*(5), 724–738. https://doi.org/10.5127/jep.028212

van Schie, K., van Veen, S. C., & Hagenaars, M. A. (2019). The effects of dual-tasks on intrusive memories following analogue trauma. *Behaviour Research and Therapy*, *120*, 103448. https://doi.org/10.1016/j.brat.2019.103448

van Schie, Kevin, & Leer, A. (2019). Lateral Eye Movements Do Not Increase False-Memory Rates: A Failed Direct-Replication Study. *Clinical Psychological Science*, *7*(5), 1159–1167. https://doi.org/10.1177/2167702619859335

3 Study II

When does Imagery Rescripting Become a Double-Edged Sword? - Investigating the Risk of Memory Distortion through Imagery Rescripting in an Online Trauma Film Study

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Abstract

Imagery Rescripting (ImRs) has proven effective in reducing involuntary emotional memories. However, it is unclear whether and when it may lead to reduced accuracy of voluntary memory. Although previous analogue studies suggest that ImRs does not pose a general risk regarding memory distortion, it can not be ruled out that ImRs could cause memory impairment under certain risk conditions. In our three-day online trauma film study, we investigated in a healthy sample (N = 267) whether specific instructions during ImRs as typically provided in clinical practice (i.e., detailed imagery with a sensory focus) increase the risk of memory distortions. Additionally, we examined whether the completeness of the original memory moderates these instruction effects. Contrary to our expectations, a sensory focus during ImRs was associated with higher memory accuracy in a recognition task, independently of the quality of the original memory. These results extend previous findings by suggesting that ImRs does not even impair memory performance when the quality of the original memory is poor and when the production of sensory-rich images is specifically encouraged. Our results question current practices employed to assess witness statement credibility, which are partly based on concerns that trauma-focused interventions like ImRs undermine memory accuracy.

Keywords: Imagery rescripting, false memory, trauma film, post-traumatic stress disorder

Introduction

Intrusive, distressing memories are a core feature of various emotional disorders (Brewin et al., 2010). Recent clinical approaches, such as Imagery Rescripting (ImRs), specifically target these memories in order to reduce associated symptoms. In ImRs, an aversive memory is first reactivated and then modified in the patient's imagination so that the outcome is perceived as being less distressing (e.g., the perpetrator is disempowered or the victim’s needs are taken care of, e.g., they are comforted and brought to safety; e.g., Arntz & Weertman, 1999; Holmes et al., 2007; Smucker et al., 1995).

While ImRs aims to reduce the involuntary and incontrollable recall of aversive memories and the associated distress, it is intended to preserve voluntary memory of factual information about an event. This is important considering the adaptive function of remembering (e.g., for future danger assessment), but also in terms of the role of trauma memory recall in legal contexts (e.g., in witness statements and the assessment of their credibility in court).

Theoretical approaches to the underlying mechanisms assume that ImRs does indeed selectively modify the *meaning* of emotional memory, but *not* the memory of *factual event details* as such (i.e., Arntz, 2012; Arntz & Weertman, 1999). Regarding the first part of this assumption, there is increasing evidence that ImRs reduces the involuntary occurrence of aversive memories and the associated emotional distress (e.g., Arntz, 2012; Morina et al., 2017). Regarding the second part of the assumption, the question of whether ImRs might unintentionally also cause distortions of memories of factual event information or even induce false memories of events that did not happen has recently gained increasing attention (e.g., Ganslmeier et al., 2022, 2023; Otgaar et al., 2021).

Current discussions about the potential of imagery-based trauma-focused interventions, such as ImRs, to cause memory distortions (e.g., Bublitz, 2020; Ganslmeier et al., 2022, 2023; Otgaar et al., 2021) point to evidence from two influential lines of memory research showing that: (1) After reactivation, consolidated memories can enter a destabilized state. In this plastic state, they are vulnerable to modification through the integration and reconsolidation of either correcting or distorting information (Beckers & Kindt, 2017; Lee, 2009; Nader et al., 2000); and (2) memories are fallible to the extent that – under certain conditions – not only can a memory of actually experienced event details be manipulated, but people can develop rich autobiographical memories for entire events that never actually happened (i.e., "false memories"; for an overview see Davis & Loftus, 2020).

For instance, research on the so-called "misinformation effect" has shown that exposure to counterfactual information after an event can reduce memory accuracy for the event (Tousignant et al., 1986; see Loftus & Klemfuss, 2023 for an overview). These studies have mainly used a three-stage experimental procedure. First, a memory was induced, for example, by showing participants a video of an event (e.g., crime scene). Then, participants were exposed to misinformation about the event. This misleading information was typically subtly integrated in post-event questions about the film content or in narrative accounts of the event (Blank & Launay, 2014). Afterwards, participants' memories of correct details about the original event and/or their endorsement of misleading details were assessed using a memory test (e.g., Brewin & Andrews, 2017; Loftus, 1975; Loftus et al., 1978).

According to the Discrepancy Detection Principle, such memory distortions are more likely to occur when an individual does not immediately detect discrepancies between a memory of the original event and post-event misinformation, and then falsely incorporates the misinformation into their memory (Tousignant et al., 1986). The ability to detect discrepancies can be influenced by various factors, such as the strength of memory of the original event, the time interval between the original event and the memory test, the subtlety of the misinformation introduced, and the presence of warnings regarding misinformation (e.g., Brewin & Andrews, 2017; Leding & Antonio, 2019; Loftus, 1992).

In addition, studies on the “imagination inflation effect” (Garry et al., 1996; Goff & Roediger, 1998) provide evidence that imagining an event increases confidence that the event has actually occurred and, in some cases, can produce a false memory of the event (e.g., Goff & Roediger, 1998; Seamon et al., 2006; Thomas & Loftus, 2002). It has also been shown that imagination can alter the stored representation of actually experienced events (Goff & Roediger, 1998) or actually seen objects (Lyle & Johnson, 2007). Imagination can influence both recent (e.g., Seamon et al., 2006) and old (e.g., Garry et al., 1996) memories. Moreover, this is the case not only if the imagined event is plausible but also if it is implausible (e.g., Sharman & Scoboria, 2009).

Such memory distortions can be explained by the Source Monitoring Framework (Johnson et al., 1993; Lindsay & Johnson, 2000), according to which inaccurate memory reports occur when a memory of an imagined event (= internal source) is falsely attributed to an actually experienced event (= external source). The more perceptual and conceptual detail the imagined event and the actually experienced event share, the higher a person’s susceptibility to such memory errors (Lyle & Johnson, 2007; Thomas et al., 2003). Accordingly, imagination instructions that include more elaboration of perceptual information and sensory detail increase susceptibility to memory distortion (e.g., Johnson et al., 1993; Thomas et al., 2003). This could be explained by the fact that people rely on the amount of sensory detail to determine the source of their memory, because actually experienced events typically contain more sensory detail than imagined events (Johnson et al., 1993; Özbek et al., 2017).

In light of these findings, it is not surprising that some authors have raised concerns that ImRs might have distorting effects on factual memory (e.g., Otgaar et al., 2021). In fact, ImRs shares some important characteristics with the experimental procedures used to demonstrate the process of memory distortion: It involves both imagination and exposure to counterfactual information during the rescripting phase.

However, the results of the few studies to date that have examined the effects of ImRs on memory accuracy did not find that the intervention distorts memories of factual event details. On the contrary, previous trauma analogue studies even found that ImRs led to improved memory performance as assessed by a free recall task (Ganslmeier et al., 2022), and did not impair (Ganslmeier et al., 2023; Siegesleitner et al., 2019) – or even improved (Hagenaars & Arntz, 2012) – memory accuracy as assessed with recognition and cued recall tasks.

Although none of the previous studies have been able to show the suspected negative impact of ImRs on the accuracy of an original event memory, the number of studies is still very small. In addition, the informative value of previous study results is limited regarding two important aspects. First, some of these studies (Hagenaars & Arntz, 2012; Siegesleitner et al., 2019) were not primarily designed to assess intervention effects on memory accuracy. Instead, memory accuracy was only investigated exploratively and/or as a secondary outcome. Hence, these studies used a relatively small number of items, that, to our knowledge, were not explicitly designed to assess memory for information that might be relevant in practical contexts, such as the legal field.

Second, the generalizability of these studies is limited by the fact that they did not take into account the specific conditions under which ImRs is typically delivered in clinical practice and that these conditions might in fact elevate the risk of memory distortions through ImRs: All studies mentioned so far assessed the effects of ImRs on relatively recent memories that were either induced minutes before the intervention took place (Hagenaars & Arntz, 2012) or up to one day before ImRs was applied (Ganslmeier et al., 2022, 2023; Siegesleitner et al., 2019). However, in clinical practice, most patients start psychological treatment months or even years after a traumatic or distressing life event has taken place; therefore, memory of certain event details may already be weak or vague in clinical populations. Moreover, recent evidence encourages the use of ImRs in the treatment of post-traumatic stress disorder (e.g., Boterhoven De Haan et al., 2020; Raabe et al., 2015), a disorder that is in part defined by “the inability to recall key features of the trauma" (criterion D 1., Diagnostic and Statistical Manual of Mental Disorders, 5th edition [DSM-5]; American Psychiatric Association, 2013). Critically, in cases where the original memory is vague, detecting discrepancies and/or monitoring the memory source can become more difficult (Johnson et al., 1993). As a result, it may become more likely that memory sources will be confused or that memory gaps will potentially be filled with false information (Loftus, 1997). Such false information can be introduced by the acceptance of misinformation (Loftus, 2005), via confabulation and autosuggestion (e.g., Ackil & Zaragoza, 1998), or via associative memory processes (Howe et al., 2009).

In addition to the quality of the original memory, it is also important to account for specific therapeutic instructions that could inadvertently have an influence on the probability of memory distortion when assessing potential unwanted effects of ImRs. For example, in clinical practice, the production of vivid, sensory-rich images during rescripting is often encouraged as this is considered necessary for therapeutic change (e.g., Arntz & Weertman, 1999). However, based on the source monitoring framework, a vivid and detailed imagination could reduce a patient's ability to correctly discriminate the sources of memory (actually experienced vs. imagined only), making patients more vulnerable to memory errors. Patient subgroups that have weak memories of their distressing or traumatic life events may be particularly vulnerable as they might have greater difficulty detecting discrepancies between actually experienced and (spontaneously) imagined information, including counterfactual information. It could be particularly risky to ask these patients to elaborate on and vividly imagine details they do not recollect during memory reactivation and rescripting.

To summarize, results from previous experimental studies suggest that ImRs does not pose a *general* risk of memory distortion (i.e., always and inevitably lead to memory impairment). However, these studies have not taken into account some factors that are typically present in the clinical use of ImRs and which, based on findings from the false memory literature, could increase the potential of ImRs to impair memory.

Aim of the current study

The main goal of the present study was to take a first step towards a systematic investigation of potential risk conditions under which ImRs could lead to memory distortions. More specifically, we focused on the impact of therapeutic instructions commonly used in clinical practice, which encourage patients to focus on sensory-perceptual information while reactivating and changing their distressing memories in their imagination. We also examined whether the effects of these instructions on memory depended on the completeness and clarity of the memory of the original event.

We conducted a three-day online trauma film study, which allowed us to examine the effects of the intervention on consolidated memories (see Ganslmeier et al., 2022, 2023; James et al., 2015; Siegesleitner et al., 2019). On the first day an aversive memory was induced using an aversive film clip, the intervention took place on the second day, and the memory test was applied on the third day.

We developed two ImRs intervention protocols, which contained specific instructions to either focus on sensory-perceptual details during memory reactivation and rescripting or *not* to focus on sensory-perceptual details during memory reactivation and rescripting. Additionally, a no-intervention control condition (NIC) was introduced to account for the effects of normal forgetting.

To manipulate the quality of the original memory, participants were presented either with a modified version of the film in order to induce an unclear and incomplete memory, or with the original version of the film to create a clearer and more complete memory.

Hypotheses

Our predictions about the effects of ImRs on memory accuracy were based on the source monitoring framework (Johnson et al., 1993) and the discrepancy detection principle (Tousignant et al., 1986). First, we expected ImRs with a sensory focus, but not ImRs without a sensory focus (or NIC) to impair memory accuracy. This should be reflected in lower memory accuracy in ImRs with a sensory-perceptual focus compared to NIC and ImRs without a sensory-perceptual focus.

Second, we hypothesized that the differential intervention effects would be moderated by the completeness and clarity of the original memory (pre-intervention): Participants with an unclear and incomplete memory of the film clip should have less accurate memories after receiving ImRs with a sensory-perceptual focus than participants with a clear and complete memory of the film clip.

Third, in line with literature on the effectiveness of ImRs for reducing psychopathology (see Morina et al., 2017) and emotional distress (e.g., Strohm et al., 2019) associated with aversive memories, we hypothesized that the two versions of ImRs intervention would each be more effective at reducing intrusions from the film clip, as well as distress and arousal associated with the film clip, as compared to the NIC.

Fourth, and finally, we expected ImRs with a sensory-perceptual focus to be more effective than ImRs without a sensory-perceptual focus and NIC. This should be reflected both 1) in a higher reduction of intrusions and 2) a greater reduction in subjective arousal and distress associated with voluntary memory recall.

We based this prediction on the fact that ImRs intervention protocols emphasize the need for vivid, sensory-rich imagery during rescripting for emotional reactivation, which is considered crucial to achieve the best intervention effects (e.g., Arntz & Weertman, 1999). In addition, we explored the effects of memory clarity and its interaction with the factor intervention in our analyses.

Methods

Participants

An a priori power analysis was conducted to calculate the appropriate sample size with regard to the proposed hypotheses on the primary outcome measure (i.e., memory accuracy). Due to the lack of similar studies from which effect sizes could be derived, a differential effect size of f = .20 (small to medium effect) was assumed. Calculations using G*Power software (ANOVA: fixed effects, special, main effects and interactions) resulted in a total sample size of N = 244 (41 participants per condition) with an $\alpha = .05$ and a statistical power of $1\text{-}\beta = .80$.

1,289 participants were recruited through advertisements in online social networks (i.e., Facebook, Instagram, student WhatsApp groups) and the online panel PsyWeb (https://psyweb.uni-muenster.de/). Exclusion criteria were (a) age below 18 or above 55 (based on findings on a decline in episodic memory performance above the age of 55, eg., Rönnlund et al., 2005; Toppala et al., 2021), (b) current suicidality, (c) self-reported current psychological or neurological disorder, (d) history of psychosis or self-injurious behavior, (e) use of beta-blockers or other anti-hypertensive medication, (f) experience of one or more traumatic events in the past, similar to the content of the film, and (g) drug intake up to 72 h before testing or more than three alcohol beverages within 24 h before testing.

Based on these criteria, 301 participants were excluded. Another 106 participants did not finish the screening questionnaire. 330 participants who completed screening did not continue with the first session. 107 participants dropped out during Session 1, 52 dropped out after Session 1, and 21 dropped out after Session 2. We had to exclude an additional 94 participants from the analyses based on failure to comply with the protocol procedure. For outcomes on the memory recognition task, we conducted an outlier analysis using a 1.5 interquartile range criterion to identify outliers within each condition (memory_unclear/ImRs_Sensory: 4 outliers, memory_clear/ImRs_Sensory: 3 outliers, memory_clear/ImRs_NotSensory: 2 outliers, memory_clear/NIC: 3 outliers). All 11 identified outliers have been excluded from the analyses, resulting in a total sample of 267 participants (153 females, 113 males, 1 non-binary, mean age = 29.80, SD = 8.92, range = 18 to 55; 91,76 % of German nationality).[1]

Participants were randomly allocated to one of six experimental conditions that resulted from the 2 (*memory*: memory_clear; memory_unclear) x3 (*intervention:* ImRs_Sensory; ImRs_NotSensory; NIC) factorial design. Participants received partial course credit or a small monetary reimbursement (10 € for complete study participation).

Materials

All materials are available at the Open Science Framework at https://osf.io/j9f85.

Trauma Film

Content

A 7-min aversive film clip from the movie "Picco" (Koch, 2010, 1:18:25 – 1:26:25) was used to induce an aversive memory. The film clip shows a group of three prisoners torturing another inmate through both physical (e.g., beatings) and psychological violence (e.g., verbal humiliations and attempts to convince the victim to commit suicide).

Memory manipulation

The completeness and clarity of the memory of the film prior to the intervention was experimentally manipulated by either showing the film clip in its original form (memory_clear) or by using a visual blur filter that covered the whole picture and a blur audio filter masking parts of the dialogues so that certain visual and auditory information was no longer clearly identifiable (memory_unclear).

[1] Results of the analyses before outlier exclusion can be found in table S3 the supplemental material on the OSF (https://doi.org/10.17605/OSF.IO/S67NC).

The film clips used were piloted in order to ensure that 1) the film clips induce an equal amount of distress and 2) memory accuracy and confidence are higher for the film clip without blur filters vs. the film clip with blur filter, as assessed by the memory recognition task (see Table S1 in the supplemental material on the OSF). The instructions for film viewing were based on a previous online trauma film study by Espinosa et al. (2023). The exact wording of the instructions for film viewing used in our study can be found on the OSF (osf.io/pqnh5, Materials, General_Instructions_Control_Questions).

Interventions

Both ImRs interventions were standardized and delivered via audio. The ImRs procedure was adapted from Arntz and Weertman (1999) and consisted of a brief imagery exercise for memory reactivation and a rescripting phase (see Kunze et al., 2017). Participants were first instructed to close their eyes and to reactivate the beginning of the scene as told. After the short reactivation (4.5 min. in ImRs_NotSensory; 6 min. in ImRs_Sensory), they rated their subjective distress and memory vividness. They were then asked to close their eyes again and to imagine the rescripted course of events as instructed (5.5 min. in ImRs_NotSensory; 8 min. in ImRs_Sensory). During rescripting, participants were instructed to imagine how the violent attacks towards the victim are stopped by prison guards who confront and disempower the perpetrators, remove them from the scene, and then take care of the victim. The exact wording and audio files of the instructions for memory reactivation and rescripting can be found on the OSF (osf.io/pqnh5, Materials).

Imagery Rescripting with sensory-perceptual focus (ImRs_Sensory)

Subjects in the ImRs_Sensory condition were instructed to imagine the scene and all changes as vividly and in as much detail as possible and to pay attention to all sensory channels throughout both the reactivation and the rescripting phase (e.g., “Now the perpetrators are being taken away in handcuffs by additional prison guards who have just arrived. *Watch closely as* *they leave the room. How do the perpetrators look to you now? What do you observe in their body language and their facial expressions?"*).

Imagery Rescripting without sensory-perceptual focus (ImRs_NotSensory)

Subjects in the ImRs_NotSensory condition were instructed to focus on the same conceptual changes to the action as in the ImRs_Sensory condition, but without the explicit instruction to imagine everything in as much detail and as vividly as possible, and without the instruction to focus on sensory-perceptual details while doing so (e.g., "Now the perpetrators are being taken away in handcuffs by additional prison guards who have just arrived. [*no further instructions*]").

No-intervention control (NIC)

Participants in the NIC group did not receive any intervention.

Measures

Baseline measures

Baseline measures were assessed for depressive symptoms using the Patient Health Questionnaire-9 (PHQ-9; Kroenke et al., 2002; German translation by Gräfe et al., 2004) and for trait anxiety using the trait form State-Trait-Anxiety-Inventory (STAI-T, Spielberger et al., 1970; German translation by Laux et al., 1981).

Manipulation Checks

Manipulation checks for stress induction and memory reactivation were performed in line with previous work (e.g., James et al., 2015, 2016). The Positive and Negative Affect Schedule (PANAS; German version: Krohne et al., 1996) was used to assess mood immediately before and after watching the film. Additionally, subjective distress (SUD) and memory vividness were assessed by visual analogue scales on a scale ranging from 0 to 100. Arousal was assessed using Self-Assessment Manikins (SAM; Bradley & Lang, 1994). SUD, SAM, and memory vividness were assessed at different timepoints (i.e., pre- and post-film viewing, pre- and post-memory reactivation and pre- and post-rescripting, see Figure 2).

Control variables

Control questions about the film and audio content, as well as about compliance with the experimental requirements (e.g., being alone and undisturbed, whether and for how long participants looked away from the screen, etc.), were administered as compliance checks. We assessed runtime variables for the duration of film viewing and the time delay between each time of assessment for further compliance checks. Further details on these measures as well as the exact items we used to assess protocol compliance can be found in the document "General_instructions_control_questions.pdf" in the materials section on the OSF (https://osf.io/j9f85).

Memory recognition task

Memory accuracy was assessed by means of a memory recognition task that contained 39 questions with one true and two false answer options as well as the option "I don't know" (e.g., "What was used to hit the victim in the back of the head?"; true answer: iron bar, false answers: baseball bat, broomstick). Following Ganslmeier et al. (2022), questions were chosen based on a guideline for police examinations (Hermanutz & Schröder, 2015) and focused on the place of action (e.g., "How many windows were in the room?"), the persons involved (e.g., "Who put the plastic bag over the victim's head?") and the events taking place in the film (e.g., "How many cuts was the victim injured with on the forearm?"). The total number of correct answers, the total number of wrong answers, and the total number of "I don't know" answers constituted the primary outcome measures for memory accuracy. The items used in the memory recognition task were piloted in order to ensure appropriate difficulty of the items (i.e., we aimed for an approximately balanced number of items across different levels of difficulty ranging from very difficult to very easy, and replaced items where necessary to meet this criterion). Item difficulties for our pilot data can be found in table S4 in the supplemental material on the OSF.

Intrusion diary

The quantity (total number) and quality (type of memory as defined below; content of the memory; trigger situation; distress and vividness, each scored on a scale from 0 – 10) of intrusive memories in response to the film clip was assessed pre- and post-intervention at t2 and t3 by means of a retrospective summary of the total number of intrusions since the last study appointment (e.g., Hackmann et al., 2004; Rattel et al., 2019).

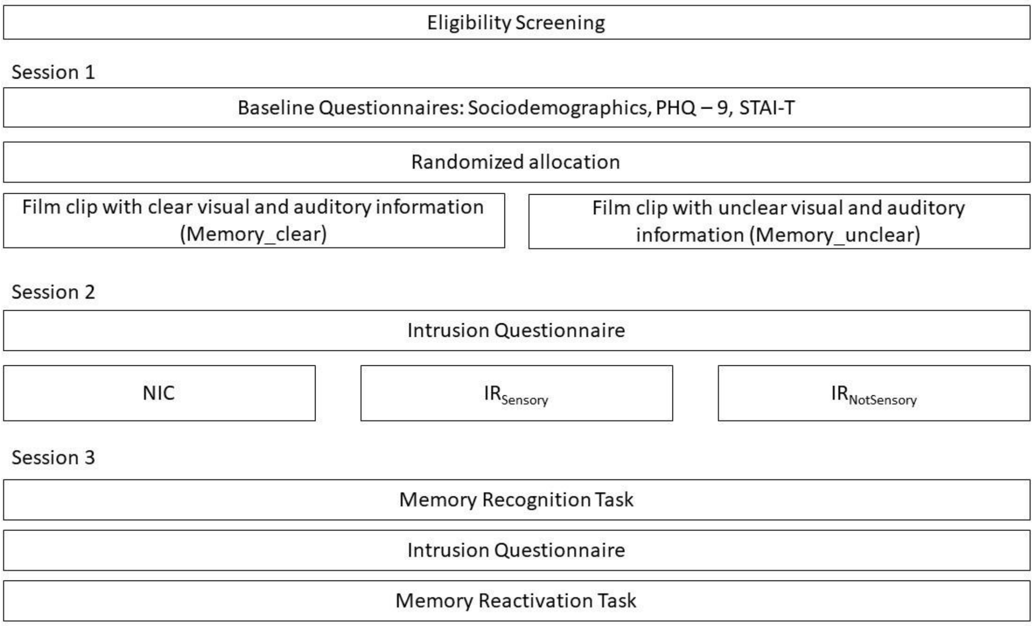
Intrusive memories were defined as spontaneously occurring involuntary memories of the film clip, which could be mental images, sounds, verbal thoughts, emotions, bodily sensations, or a combination. The reduction of the total number of intrusions from pre- to post-intervention was assessed as a measure of intervention effectiveness.

Procedure

See Figure 2 for a schematic overview of the study procedure.

Figure 2

Schematic Overview of the Study Procedure



Note. ImRs_Sensory Imagery Rescripting with sensory-perceptual focus, *ImRs_NotSensory* Imagery Rescripting without sensory-perceptual focus, *NIC* no-intervention control group, *PHQ* Patient Health Questionnaire-9, *STAI-T* trait form of the State-Trait-Anxiety-Inventory.

Online Screening

In a brief online screening, the participants were given an overview of the study procedure and the requirements for study participation. Participants were informed of the distressing nature of the film and that they could withdraw from the study at any point. After providing informed consent, the eligibility criteria were assessed. Those who met the inclusion criteria received additional information regarding the continuation of the study. Participants who did not meet the inclusion criteria were not invited to attend future appointments.

At the start of each session, participants were reminded of the requirements of the experiment (e.g., being in a quiet and undisturbed environment and using a laptop or PC instead of a smartphone or tablet). Those who were unable to meet these requirements were asked to reschedule the respective session for a later time when they could meet the conditions.

Session 1

At the beginning of the first session, participants completed a questionnaire on sociodemographic data (age, gender, education, nationality) and baseline questionnaires. A short health questionnaire was administered to gather information about participants' sleep quality and duration, drug and alcohol consumption in the days prior to the study, neurological disorders, and presence of uncorrected visual impairments. Participants were then randomly allocated to one of the six conditions and watched the trauma film clip. SUD, SAM, and PANAS were assessed pre- and post-film viewing.

Session 2

The second session began with the completion of the health questionnaire, followed by the intrusion questionnaire. For participants in the NIC condition, the second session ended after they filled out these questionnaires. Participants in the intervention conditions continued with pre-memory reactivation assessments of SUD, SAM, and memory vividness, followed by a brief imagery exercise to reactivate their memories. After the imagery exercise, participants completed post-assessments of SUD, SAM, and memory vividness. The session then proceeded with the imagery rescripting phase, followed by post-rescripting-assessments of SUD, SAM, and vividness.

Session 3

Session 3 started with the health questionnaire, followed by the memory recognition task and the second administration of the intrusion questionnaire. Subsequently, the memory of the film was again reactivated in a short imagery exercise, preceded and followed by SUD, SAM, and memory vividness assessments. The session ended with a debriefing of the participants.

Statistical Analyses

Baseline Differences

To identify possible covariates, three univariate ANOVAs on PHQ – 9, STAI-T, and PANAS (pre-film clip) were conducted in order to assess differences between the six groups (*memory:* memory_unclear, memory_clear x i*ntervention:* IR_Sensory, IRNot_Sensory, NIC) in baseline responding.

Manipulation Checks

Emotional distress caused by the trauma film

Four mixed 2 (*memory*: memory_unclear vs. memory_clear) x 3 (*intervention*: ImRs_Sensory vs. ImRs_NotSensory vs. NIC) x 2 (*time*: pre-film vs. post-film) ANOVAs were conducted to check whether both film clips were equally successful in inducing distress (SUD), arousal (SAM), and negative affect, and in reducing positive affect (PANAS) in all experimental groups in Session 2 (the intervention took place only in Session 2).

Memory Reactivation pre-intervention in Session 2

To assess memory reactivation effects in the intervention groups in Session 2 (prior to the interventions) on SUD, SAM, and memory vividness, three mixed 2 (*memory*: memory_unclear vs. memory_clear) x 2 (*intervention*: ImRs_Sensory vs. ImRs_NotSensory) x 2 (*time*: pre-reactivation vs. post-reactivation) ANOVAs were performed.

Analyses of primary hypotheses

Hypothesis 1 (group differences in memory accuracy) & hypothesis 2 (moderating effect of memory completeness and clarity)

To assess the effect of intervention on memory accuracy and to assess the potential moderating effects of the completeness and clarity of the original memory (pre-intervention) on memory accuracy, we conducted three 2 (*memory:* memory_unclear, memory_clear) x 3 (*intervention:* IR_Sensory, IR_Not_Sensory, NIC) ANOVAs on the number of 1) correct answers, 2) incorrect answers, and 3) "I don't know" answers in the memory recognition task.

Hypothesis 3 & hypothesis 4 (Group differences in intrusions, distress, arousal; Session 3)

Group differences reflecting the number of participants who did not develop any intrusive memories within the first 24 hours after the film viewing were explored using chi-square tests (Siegesleitner et al., 2019).

Due to zero inflation in the data, a 2-level Poisson regression model was conducted instead of the pre-registered mixed ANOVA in order to assess group differences in the reduction of intrusions between Session 2 and Session 3, with the variable *time* on level 1 and the variables *memory* and *intervention* on level 2 to predict the number of intrusions. NIC (*intervention*), memory_unclear (*memory*), and intrusions measured at Session 2 (*time*) were used as reference levels.

To analyze intervention effects on memory distress (*SUD)* and arousal (*SAM*) in response to memory reactivation in Session 3 of study participation, two mixed 2 (*memory*: memory_unclear vs. memory_clear) x 3 (*intervention*: ImRs_Sensory vs. ImRs_NotSensory vs. NIC) x 2 (*time*: pre-reactivation vs. post-reactivation) ANOVAs were conducted. Bonferroni corrections were applied for post-hoc analyses.

Exploratory analyses

To explore group differences in memory confidence ratings, a 2 (memory: memory_unclear vs. memory_clear) x 3 (intervention: ImRs_Sensory vs. ImRs_NotSensory vs. NIC) multivariate analysis of variance (MANOVA) was carried out on mean confidence ratings for correct answers and for wrong answers as dependent variables.

All analyses described above were conducted in R (R Development Core Team, 2023), using the following packages: 'dplyr' (Wickham, François, et al., 2023) and 'car' (Fox & Weisberg, 2019) for data wrangling, 'psych' (Revelle, 2023) for data screening and calculating descriptive statistics, ‘ggplot2’(Wickham et al., 2023), ‘ggpubr’ (Kassambara, 2023a) and ‘cowplot’ (Wilke, 2023) for visualizing data, ‘rstatix’ (Kassambara, 2023b) for basic statistical tests, ‘glmmTMB’ (Brooks et al., 2023) for computing mixed-effects models and ‘MBESS’ (Kelley, 2023) for calculating confidence intervals.

Results

For effect sizes, 90% confidence intervals were computed (Steiger, 2004). Bonferroni corrections were conducted for post-hoc tests.

Baseline and control variable differences between conditions

As illustrated in Table 8, there were no significant differences between the six groups (*memory* x *intervention*) in terms of sociodemographic or control variables.

Table 8

Means (M) and Standard Deviations (SD) of Sociodemographic and Control Variables

Variables	Condition						Statistics	p
	ImRs_Sensory		ImRs_NotSensory		NIC			
	Clear (*n* = 49)	Unclear (*n* = 39)	Clear (*n* = 48)	Unclear (*n* = 41)	Clear (*n* = 45)	Unclear (*n* = 45)		
Sociodemographic variables	*M(SD)*	*M(SD)*	*M(SD)*	*M(SD)*	*M(SD)*	*M(SD)*		
Age	30.12(8.96)	31.15(10.60)	29.17(7.53)	28.59(8.81)	30.89(9.77)	28.96(8.03)	*F*(5, 261) = 0.60	.698
Years of education	16.06(4.95)	14.17(4.54)	15.44(4.13)	15.96(5.81)	16.27(3.60)	16.20(2.77)	F(5, 254) = 1.31	.259
	%	%	%	%	%	%		
Gender (female)	55.10	56.41	56.25	60.98	60.00	55.55	$\chi2(5) = 0.55$	.99
Student (yes)	33.33	48.98	48.78	53.66	46.67	51.11	$\chi2(5) = 3.30$	.653
Control variables	*M(SD)*	*M(SD)*	*M(SD)*	*M(SD)*	*M(SD)*	*M(SD)*		
Sleep before Session 1	7.83(1.01)	7.68(1.02)	7.71(1.34)	7.76(1.44)	7.55(1.24)	7.70(1.05)	*F*(5, 261) = 0.27	.932
Sleep before Session 2	7.73(1.19)	7.45(0.97)	7.31(1.32)	7.60(1.15)	7.51(0.98)	7.52(1.15)	*F*(5, 261) = 0.76	.580
Sleep before Session 3	7.57(1.26)	7.55(1.13)	7.48(1.58)	7.50(1.53)	7.21(1.07)	7.71(1.06)	*F*(5, 261) = 0.73	.599
PHQ	3.49(3.35)	3.92(3.35)	4.25(3.64)	4.98(4.17)	4.56(4.05)	4.64(3.50)	*F*(5, 261) = 0.95	.447
STAI-T	37.06(9.73)	35.85(8.95)	37.21(9.32)	38.61(9.54)	38.00(11.08)	34.96(7.34)	*F*(5, 261) = 0.89	.489
Compliance check variables								
Missed film content (%)	0.43(1.71)	0.67(1.74)	0.92(2.28)	0.41(1.47)	1.07(2.58)	0.36(1.25)	*F*(5, 261) = 1.09	.364
Time between S1 & S2 (ks)	91.93(11.96)	94.17(13.38)	92.36(10.89)	89.33(7.15)	96.30(14.13)	91.70(11.53)	*F*(5, 261) = 1.75	.123
Time between S2 & S3 (ks)	93,842(13.34)	91.68(10.88)	91.59(9.00)	90.40(8.39)	92.76(11.97)	91.74(10.78)	*F*(5, 261) = 0.52	.759

Note. *ImRs_Sensory* Imagery Rescripting with sensory-perceptual focus, *ImRs_NotSensory* Imagery Rescripting without sensory-perceptual focus, *NIC* no-intervention control group, *PHQ* Patient Health Questionnaire-9, *STAI-T* trait form of the State-Trait-Anxiety-Inventory, *ks* 1000 seconds, *S1* Session 1, *S2* Session 2, *S3* Session 3.

Manipulation checks

Descriptive statistics of all manipulation check scores for SUD, SAM, vividness, and PANAS are displayed in Tables S1 and S2 in the Supplemental Material on the OSF (https://osf.io/s5m4e).

Emotional distress caused by the trauma film

In all ANOVAs, a significant main effect of time was found (SUD: $F(1, 261) = 370.13$, $p < 0.001$, $\eta_p^2 = 0.59$, 90% *CI* [0.53, 0.63]; SAM: $F(1, 261) = 685.90$, $p < 0.001$, $\eta_p^2 = 0.72$, 90% *CI* [0.68, 0.76]; negative affect: $F(1, 261) = 662.11$, $p < 0.001$, $\eta_p^2 = 0.72$, 90% *CI* [0.67, 0.75]; positive affect: $F(1, 261) = 576.59$, $p < 0.001$, $\eta_p^2 = 0.69$, 90% *CI* [0.64, 0.73]), indicating an increase of subjective distress (SUD), subjective arousal (SAM), and negative affect, as well as a decrease of positive affect from pre- to post-film viewing. No main effects emerged for memory (all $Fs < 0.71$, all $ps > .399$, all $\eta_p^2 = 0.00$), or intervention (all $Fs < 2.61$, all $ps > .075$, all $\eta_p^2 < 0.02$), or interaction effects (all $Fs < 2.43$, all $ps > .090$, all $\eta_p^2 < 0.02$) in these analyses.

Memory Reactivation pre-intervention in Session 2

Subjective distress

Regarding memory reactivation in the intervention groups in Session 2 (prior to the interventions), a large main effect of time showed higher post- than pre-memory reactivation SUD scores, $F(1, 173) = 192.32$, $p < .001$, $\eta_p^2 = 0.53$, 90% *CI* [0.44, 0.59]. There was also a small main effect of *intervention*, $F(1, 173) = 5.12$, $p = .025$, $\eta_p^2 = 0.03$, 90% *CI* [0.00, 0.08], indicating higher *SUD* in the ImRs_Sensory condition than in the ImRs_NotSensory condition. Neither the main effect of *memory*, $F(1, 173) = 0.16$, $p = .690$, $\eta_p^2 = 0.00$, 90% *CI* [0.00, 0.02], nor any interaction effects were significant (all $Fs < 0.39$, all $ps > .536$, all $\eta_p^2 < 0.02$).

Subjective arousal

For SAM, we found a significant main effect of *time*, $F(1, 173) = 210.39$, $p < .001$, $\eta_p^2 = 0.55$, 90% *CI* [0.47, 0.61] indicating an increase in subjective arousal over time, and a significant main effect of *intervention*, $F(1, 173) = 5.38$, $p = .022$, $\eta_p^2 = 0.03$, 90% *CI* [0.00, 0.08], with higher scores in the ImRs_Sensory condition than in the ImRs_NotSensory condition. We found no significant main effect of *memory*, $F(1, 173) = 0.45$, $p = .502$, $\eta_p^2 = 0.00$, 90% *CI* [0.00, 0.03], nor any interaction effects (all *F*s < 0.60, all *p*s > .471, all $\eta_p^2 < 0.01$).

Memory vividness

For memory vividness, a main effect of *time*, $F(1, 173) = 44.45$, $p < .001$, $\eta_p^2 = 0.20$, 90% *CI* [0.12, 0.29], indicated a more vivid memory representation after memory reactivation. There were no main effects of *memory* or *intervention*, both *Fs* < 2.33, both *ps* >.129, both $\eta_p^2 < 0.01$. We found a significant interaction between *memory* and *time*, $F(1, 173) = 6.13$, $p = .014$, $\eta_p^2 = 0.03$, 90% *CI* [0.00, 0.09] with a higher increase of memory vividness from pre- to post memory reactivation in the memory_unclear than in the memory_clear condition. No other significant interaction effects were observed (all *F*s < 1.50, *p*s > .223, all $\eta_p^2 < 0.01$).

Main analyses

Descriptive statistics for the results of the main analyses can be found in Table 9.

Table 9

Means (M) and Standard Deviations (SD) of Outcome Variables for Intervention Effectiveness and Memoru Accuracy

Variables	ImRs_Sensory		ImRs_NotSensory		NIC	
	Clear (*n* = 49)	Unclear (*n* = 39)	Clear (*n* = 48)	Unclear (*n* = 41)	Clear (*n* = 45)	Unclear (*n* = 45)
Intrusions	*n(%)*	*n(%)*	*n(%)*	*n(%)*	*n(%)*	*n(%)*
Number of participants who reported at least one intrusion after Session 1	11(22.45)	8(20.51)	9(18.75)	10(24.39)	10(22.22)	4(8.89)
Number of participants who reported at least one intrusion after Session 2	5(10.20)	1(2.56)	4(8.33)	3(7.32)	9(20.00)	3(6.67)
	M(SD)	*M(SD)*	*M(SD)*	*M(SD)*	*M(SD)*	*M(SD)*
Number of intrusions after Session 1	0.45(0.94)	0.56(1.71)	0.48(1.11)	0.46(1.03)	0.76(1.68)	0.20(0.73)
Number of intrusions after Session 2	0.12(0.39)	0.03(0.16)	0.10(0.37)	0.17(0.80)	0.40(0.94)	0.11(0.44)
Memory reactivation at Session 3						
SUD pre reactivation	17.74(18.85)	19.28(17.65)	25.71(23.25)	20.85(21.04)	23.27(20.93)	17.84(19.12)
SUD post reactivation	32.63(24.01)	32.67(22.87)	44.04(27.37)	38.10(23.72)	46.89(26.85)	38.49(25.60)
SAM post reactivation	4.02(2.04)	3.74(1.98)	4.67(1.98)	4.12(1.99)	5.22(2.22)	4.73(1.92)
vividness pre reactivation	58.84(24.87)	48.15(26.68)	51.67(25.97)	42.61(22.73)	61.47(23.73)	50.87(26.02)
vividness post reactivation	68.06(23.03)	57.72(27.33)	64.33(21.68)	53.51(51.52)	65.98(22.50)	54.24(24.37)
Memory Recognition Task						
Right answers	22.98(4.54)	17.82(3.63)	22.12(4.72)	16.24(3.75)	21.58(4.36)	15.51(4.08)
Wrong answers	7.71(2.89)	9.38(4.25)	7.42(3.31)	8.37(3.40)	7.18(3.35)	9.04(4.12)
I don't know answers	7.31(4.18)	10.79(6.15)	8.46(5.46)	13.39(6.05)	9.24(5.09)	13.44(5.97)
Memory confidence	75.79(14.90)	66.48(15.00)	73.58(15.82)	63.31(14.48)	73.52(14.55)	61.52(19.92)

Note. *ImRs_Sensory* Imagery Rescripting with sensory-perceptual focus, *ImRs_NotSensory* Imagery Rescripting without sensory-perceptual focus, *NIC* no-intervention control group, *SUD* Subjective Stress, *SAM* Self-Assessment Manikins.

Memory accuracy

Number of correct answers

Descriptive statistics for memory recognition task responses are presented in Table 9. Regarding correct answers, a main effect of memory, $F(1, 261) = 120.52$, $p < .001$, $\eta p^2 = 0.32$, 90% CI [0.24, 0.38], showed significantly more correct answers in the memory_clear condition than in the memory_unclear condition. There was also a main effect of *intervention*, $F(2, 261) = 4,38$, $p = .032$, $\eta_p^2 = 0.03$, 90% *CI* [0.00, 0.07]. Bonferroni-corrected pairwise testing revealed that the mean number of correct answers was significantly higher in the ImRs_Sensory condition than in the NIC condition ($p_{adj} = .016$). No differences were found between ImRs_Sensory and ImRs_NotSensory ($p_{adj} = .289$) or between ImRs_NotSensory and NIC ($p_{adj} = .760$). In addition, there was no significant interaction effect between *memory* and *intervention*, $F(2, 261) = 0.28$, $p = .754$, $\eta_p^2 = 0.00$, 90% *CI* [0.00, 0.01] (See Figure 3A).

Number of wrong answers

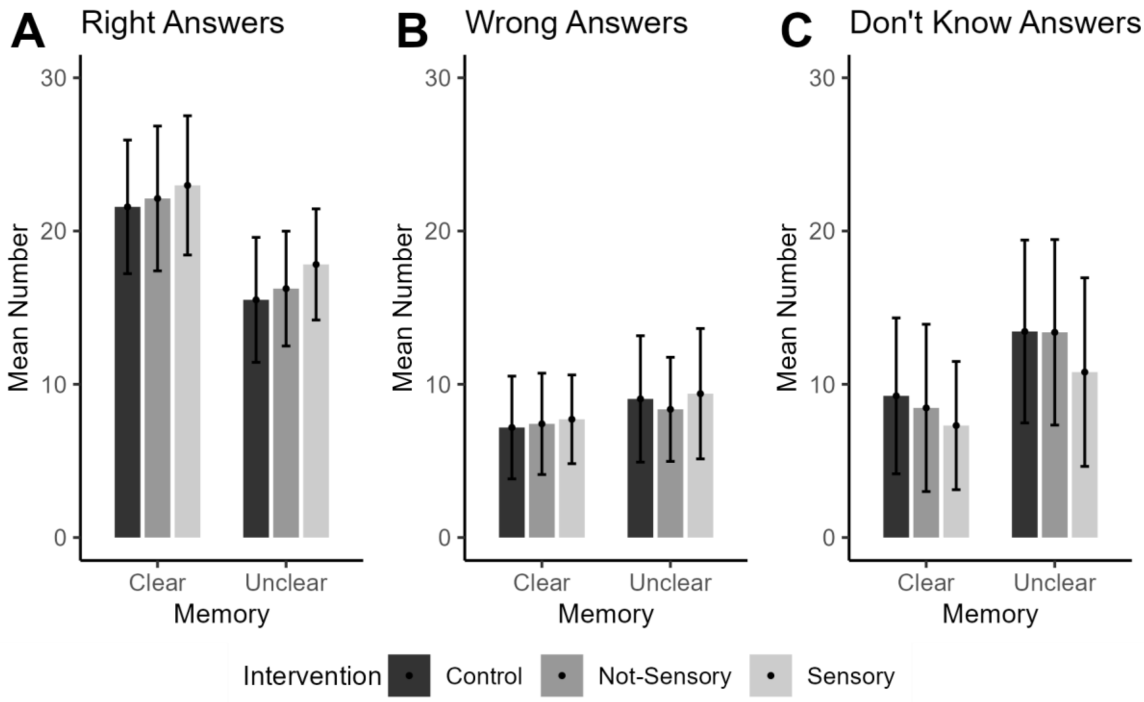
For wrong answers, the ANOVA yielded a significant main effect of *memory*, $F(1, 261) = 11.70$, $p = .001$, $\eta_p^2 = 0.04$, 90% *CI* [0.01, 0.08], with more wrong answers in the memory_unclear condition. However, neither the main effect of *intervention* ($F(2, 261) = 0.78$, $p = .461$, $\eta_p^2 = 0.01$, 90% *CI* [0.00, 0.02]) nor the interaction effect ($F(2, 261) = 0.41$, $p = .665$, $\eta_p^2 = 0.00$, 90% *CI* [0.00, 0.02]) reached significance (See Figure 3B).

Number of "I don't know" answers

Looking at the "I don't know" answers, significantly higher scores were obtained in the memory_unclear condition, $F(1, 261) = 39.22$, $p < .001$, $\eta_p^2 = 0.13$, 90% *CI* [0.07, 0.19]. Additionally, a main effect of *intervention* was found, $F(2, 261) = 4,36$, $p = .032$, $\eta_p^2 = 0.03$, 90% *CI* [0.00, 0.07]. Bonferroni-corrected pairwise testing revealed that the mean number of "I don't know" answers was significantly lower in the ImRs_Sensory condition than in the NIC condition ($p_{adj} = .014$), but did not differ between ImRs_Sensory and ImRs_NotSensory ($p_{adj} = .101$) or between ImRs_NotSensory and NIC ($p_{adj} = 1.000$). There was no interaction effect between *memory* and *intervention*, $F(2, 261) = 0.38$, $p = .685$, $\eta_p^2 = 0.00$, 90% *CI* [0.00, 0.01] (See Figure 3C).

Figure 3

Memory Recognition Task responses displayed separately for each intervention and film version



Note. Error bars represent ± one standard deviation.

Intrusions

For descriptive statistics, see Table 9. No differences were found between groups regarding the number of intrusions measured at t2 and t3 (See Table 10). $\chi 2$ test revealed that the number of participants who did not develop any intrusive memories within the first 24 hours did not differ between film versions, $\chi 2(1) = 0.55$, $p = .46$.

Table 10

Multilevel Poisson Regression Model Predicting the Course of Intrusive Memories with the Predictors Time (Session 2, Session 3), Memory (memory_unclear vs. memory_clear), and Intervention (NIC, ImRs_NotSensory, ImRs_Sensory)

Predictor	Estimates (SE)	95% CI	z	p
Session 2 vs. session 3	-0.75(0.75)	[-2.22; 0.72]	-1.00	.316
Memory_unclear vs. memory_clear	1.05(0.58)	[-0.09; 2.19]	1.81	.071
NIC vs. ImRs_NotSensory	0.30(0.60)	[-0.87; 1.48]	0.51	.613
NIC vs. ImRs_Sensory	0.73(0.61)	[-0.46; 1.92]	1.20	.230
Session 3 : memory_clear	0.10(0.84)	[-1.54; 1.74]	0.12	.903
Session 3 : ImRs_NotSensory	0.32(0.97)	[-1.58; 2.23]	0.33	.741
Session 3 : ImRs_Sensory	-2.28(1.32)	[-4.87; 0.32]	-1.72	.086
Memory_clear : ImRs_NotSensory	-0.69(0.72)	[-2.11; 0.72]	-0.96	.337
Memory_clear : ImRs_Sensory	-1.38(0.72)	[-2.79; 0.03]	-1.91	.056
Session 3 : memory_clear : ImRs_NotSensory	-1.22(1.19)	[-3.56; 1.12]	-1.03	.306
Session 3 : memory_clear : ImRs_Sensory	1.78(1.48)	[-1.12; 4.68]	1.20	.229

Note. ImRs_Sensory Imagery Rescripting with sensory-perceptual focus, *ImRs_NotSensory* Imagery Rescripting without sensory-perceptual focus, *NIC* no-intervention control group.

Subjective distress and arousal associated with memory reactivation at Session 3

Subjective distress

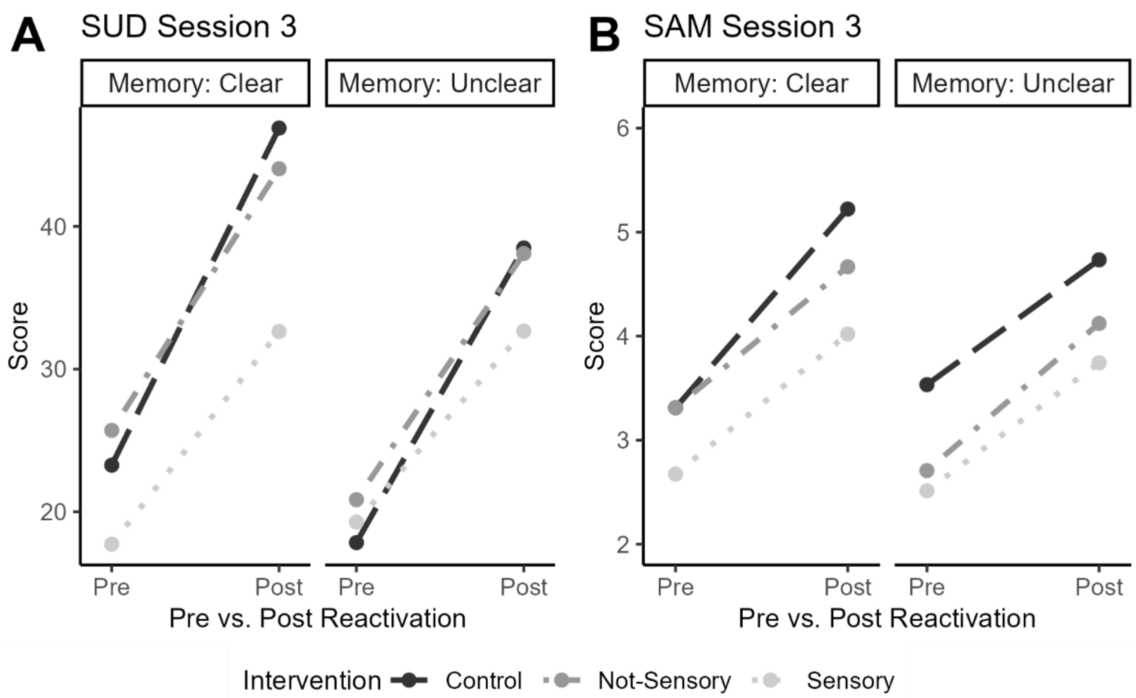
Concerning SUD scores, a main effect of *time* was observed, $F(1, 261) = 3.62$, $p < .001$, $\eta_p^2 = 0.46$, 90% *CI* [0.38, 0.52]. Additionally, a significant interaction effect was found between *intervention* and *time*, $F(1, 261) = 3.6$, $p = .028$, $\eta_p^2 = 0.03$, 90% *CI* [0.00, 0.06]. There was a significant simple main effect of *intervention* at post-reactivation, $F(2, 264) = 4.12$, $p_{adj} = .034$, but not at pre-reactivation, $F(2, 264) = 1.38$, $p_{adj} = .504$. Simple pairwise comparison revealed a significantly lower post-reactivation SUD in the ImRs_Sensory condition than in the NIC, $p_{adj} = .025$. There was no significant difference between ImRs_Sensory and ImRs_NotSensory ($p_{adj} = .070$), nor between ImRs_NotSensory and NIC ($p_{adj} = 1.000$). There was no further significant main effect or interaction effect (all *F*s < 2.76, *p*s > .065, all $\eta_p^2 < 0.02$); See Figure 4A).

Subjective arousal

For SAM scores, a significant main effect of *intervention*, $F(2, 261) = 6.83$, $p = .001$, $\eta_p^2 = 0.05$, 90% *CI* [0.01, 0.09], and a significant increase over *time*, $F(1, 261) = 228.59$, $p < .001$, $\eta_p^2 = 0.47$, 90% *CI* [0.39, 0.52], were found. Bonferroni-corrected pairwise t-tests revealed significantly lower SAM scores in the ImRs_Sensory condition compared to the NIC $p_{adj} < .001$. There was no significant difference between ImRs_NotSensory and NIC, $p_{adj} = .078$, nor between ImRs_Sensory and ImRs_NotSensory, $p_{adj} = .081$. All other effects were not significant (all *F*s < 2.11, *p*s > .147, all $\eta_p^2 < 0.01$; See Figure 4B).

Figure 4

Subjective distress (SUD) and arousal (SAM) before and after memory reactivation in Session 3



Exploratory analyses

Memory confidence rating

Due to missing data on confidence ratings, four participants were excluded from the MANOVA. There was no main effect of intervention, $F(4, 516) = 1.64$, $p = .163$, $\eta_p^2 = 0.01$, 90% *CI* [0.00, 0.03], Pillai's Trace = 0.03, nor an interaction effect between *memory* and *intervention*, $F(4, 516) = 1.17$, $p = .324$, $\eta_p^2 = 0.00$, 90% *CI* [0.00, 0.02], Pillai's Trace = 0.02, on the combined dependent variables. There was a significant main effect of *memory*, $F(2, 257) = 12.60$, $p < .001$, $\eta_p^2 = 0.09$, 90% *CI* [0.04, 0.14], Pillai's Trace = 0.09. Two post-hoc ANOVAs were conducted for mean confidence ratings for right answers and mean confidence ratings for wrong answers. Results showed significantly higher confidence ratings for right answers, $F(1, 258) = 24.13$, $p < .001$, $\eta_p^2 = 0.09$, 90% *CI* [0.04, 0.14], as well as significantly higher ratings for wrong answers, $F(1, 261) = 12.27$, $p = .001$, $\eta_p^2 = 0.05$, 90% *CI* [0.01, 0.09], in the memory_clear group than in the memory_unclear group.

Discussion

The aim of the present three-day online trauma film study was to investigate potential risk conditions under which ImRs could lead to memory distortions.

The main finding of the present study was, contrary to our expectations, that participants who received ImRs with a sensory-perceptual focus did *not* show impaired memory after the intervention as compared to ImRs without a sensory-perceptual focus and a NIC group. Instead, they even showed significantly *better* memory performance after the intervention than participants who had received no intervention. This was reflected in both a higher total number of correct memory recognition answers and a lower number of "I don't know answers" in the ImRs_Sensory group. Moreover, we did not find any group differences in the number of incorrect answers, nor did we find differences in the mean memory confidence ratings.

Interestingly, this was true even for participants who had an incomplete and unclear original memory.

Although these results are not in line with our hypotheses, they align with previous research, which also did not find any adverse effects of ImRs on memory accuracy (Ganslmeier et al., 2022, 2023; Hagenaars & Arntz, 2012; Siegesleitner et al., 2019). Moreover, our results extend these earlier findings by suggesting that a sensory-perceptual focus during imaginative reactivation and subsequent rescripting of the memory does not increase the risk of memory distortion, not even in cases of incomplete and unclear original memories.

We based our predictions on findings in the false memory literature that highlight specific conditions under which the imagination of counterfactual content, as found in ImRs, is more likely to result in memory distortions. However, the unanticipated findings in the present study may stem from inherent dissimilarities between the ImRs utilized in our study and the experimental procedures employed in previous false memory literature. The latter were specifically designed to demonstrate the malleability of memories and differ in crucial aspects from ImRs as clinically applied. These methodological differences could potentially account for the observed variations in their impact on the recollection of events. For example, it is conceivable that the way in which the memory manipulation is introduced might play a crucial role. Based on the ImRs scripts used in clinical practice (e.g., Arntz & Weertman, 1999) and in earlier studies (Ganslmeier et al., 2022, 2023; Siegesleitner et al., 2019), participants in our study were explicitly informed prior to the intervention that they would be asked later to use imagery to modify their memory of the film. In contrast, in typical misinformation studies participants are usually unaware of the memory manipulation. In line with our finding, it has been shown that warning participants about the possibility of exposure to misinformation before the presentation of misinformation often reduces the misinformation effect (e.g., Greene et al., 1982; Karanian et al., 2020). The transparent and explicit introduction of the fact that imagined changes to the memory will be part of the intervention might produce similar warning effects in ImRs and thereby prevent participants from experiencing memory distortion.

Furthermore, our assumption that a sensory-perceptual instruction focus would increase the potential of ImRs to distort memory was based on earlier evidence suggesting that the more sensory-perceptual detail an imagined event contains, the greater the risk of memory distortions due to memory source confusions (i.e., actually experienced vs. imagined events; Johnson et al., 1993; Thomas et al., 2003). However, unlike memories of events that have actually been experienced, memories of imagined events usually also contain more information about cognitive processes involved in mentally creating the image (Goff & Roediger, 1998; Johnson et al., 1988). It has been shown that people determine the memory source depending on how many cognitive processes are associated with a memory (Johnson et al., 1988). In our study, participants in the ImRs_Sensory condition had to perform complex cognitive operations that not only involved imagining the course of events and how they change (as in the ImRs_NotSensory condition), but also involved mentally creating additional sensory details, such as the sound of the protagonists' voices. This might have facilitated correct source monitoring and, as a result, reduced participants' susceptibility to memory distortion in the ImRs_Sensory group as compared to participants in the ImRs_NotSensory group.

The finding that participants in the ImRs_Sensory group did not exhibit the expected memory distortion, and even performed better in the memory recognition task in terms of number of correct answers, might also be explained by rehearsal effects (Roediger & Butler, 2011). Both ImRs conditions required participants to rehearse (parts of) their memory, whereas participants in the NIC group did not have to reactivate their memory. Moreover, research on guided imagery as a retrieval technique has shown that imagery can work as a retrieval cue, facilitating correct recall (Billings et al., 1995; Hyman & Pentland, 1996; Nori et al., 2014). Even though both ImRs conditions involved rehearsal of and imagery-based modification of the memory, the higher dose (i.e., rehearsal of more details) in ImRs_Sensory may explain why only participants in the ImRs_Sensory group remembered more correct details than participants in the NIC group. Moreover, the differing amount of instructions and, consequently, intervention durations in the two ImRs conditions alone could have caused different intervention dosages. This, in turn, may have contributed to the observed results.

If replicated, our findings might also have clinical implications. ImRs intervention protocols typically emphasize the importance of patients engaging in vivid imagery, including all sensory modalities, due to findings that imagery can act like an "emotional amplifier" (Holmes & Mathews, 2010). If vivid imagery increases the risk of side effects on memory accuracy, it would be recommendable to decrease vividness, which may in turn reduce the effectiveness of the intervention. This assumption is also supported by our data, which show that participants who received ImRs with a sensory-perceptual focus experienced the greatest reduction in subjective memory-related distress. Reassuringly, however, our findings do not suggest that instructions aimed at increasing vividness and perceptual focus will be problematic for memory retrieval.

In contrast to our hypotheses, the observed reduction of memory-related distress in our study was not paralleled by a reduction of memory-associated arousal or number of intrusions (although for memory-associated arousal, there was a descriptive trend indicating that participants in the ImRs_Sensory group showed the lowest memory-associated arousal at the end of study participation). As for intrusions, this might be due to a floor effect since the film used in our study induced only a small number of intrusions, leaving little room for improvements through the intervention (see Table 9). The film clip used in our study was not characterized primarily by images of physical or sexual violence, but rather achieved its aversive character due to the psychological violence against the victim. Moreover, the context in which the film scene takes place (a prison and violence by prison inmates) likely offered little to no associations with the participants' lives. It can therefore be assumed that during the study period participants were not frequently exposed to triggers for intrusions which might explain why we failed to measure intrusions.

Investigating the dissociation between effects of ImRs on voluntary vs. involuntary aversive memories was not the focus of the present study. However, with regard to the generalizability of our findings, it appears crucial for future studies to establish whether memory accuracy would remain unimpaired, even when the intervention shows the intended reduction of intrusive memories. Future studies should therefore consider using a different film which might be better suited to induce intrusive memories (e.g., James et al., 2015; Lau-Zhu et al., 2019). Note however, that some earlier trauma film studies aiming to model treatment effects have experienced similar complications when examining intervention effects on intrusive memories, even after using different film clips, in that they either failed to produce a sufficient initial number of intrusions or found a rapid decline in intrusions, independently of any intervention (e.g., James et al., 2016; Siegesleitner et al., 2019, 2020). An alternative for future studies could therefore be to not only look at intrusion frequency, but to incorporate alternative/additional variables, such as intrusion load, reactivity to triggers, psychophysiological responses, etc.

In sum, our findings are in line with theoretical approaches proposing that ImRs might selectively change the meaning of and emotions associated with distressing memories *without* impairing memory of factual event details (e.g., Arntz, 2012). The findings also align with earlier studies showing a dissociation between the effects of ImRs on memory distress vs. memory accuracy (e.g., Hagenaars & Arntz, 2012; Siegesleitner et al., 2019). However, it remains unclear what underlying memory processes drive these effects. It has been proposed that ImRs might modify the original memory trace through memory reconsolidation interference (Arntz, 2012; Dibbets & Arntz, 2016), thereby removing the emotional component of the memory but leaving declarative memory components intact. It has been demonstrated that such selective memory modification is indeed possible through pharmacological (e.g., Beckers & Kindt, 2017; Nader et al., 2000; Sevenster et al., 2012; Soeter & Kindt, 2010) and behavioral manipulations (e.g., Golkar et al., 2017; Lau-Zhu et al., 2019; Monfils et al., 2009; Schiller et al., 2010). However, to date, it is not known whether these results can be translated to psychological interventions such as ImRs or whether other processes might account for the observed effects. For example, retrieval competition theory (Brewin, 2006) offers an alternative explanation according to which ImRs may create a new, more positively valenced memory trace that competes with the original aversive memory representation at retrieval. While this was not the primary question of the present study, investigating the potential for reconsolidation-based memory modification through ImRs is of high clinical relevance as it could mean more stable treatment effects (Beckers & Kindt, 2017). Future research is needed to address this topic.

Strengths and limitations

Our study has a number of important strengths. First, our study is the first to systematically investigate how the effects of ImRs on memory accuracy might be influenced both by specific therapeutic instructions and by the quality of memories typically found in clinical practice. Second, we designed our items to assess memory accuracy with a particular emphasis on information that holds practical relevance, especially within the legal context, including aspects such as identifying features of the perpetrators and the chronology of events. Third, using standardized intervention protocols allowed us high experimental control over the contents imagined during the interventions. Finally, it is important to note that when examining the memory effects of ImRs, even small effects towards an impairment of memory must be ruled out. Therefore, a strength of our study is that we powered it to detect small effects.

Despite these strengths, the results of the present study must also be interpreted in light of some limitations. First, it is worth mentioning that we did not collect information on the participants' ethnic identification or the cultural background. We therefore cannot say how representative our results are for people from different ethnic and cultural contexts.

Second, using an analogue design enabled us to experimentally control and manipulate memory content, which was crucial for the purpose of our study. However, our sample might therefore have differed from clinical samples in terms of important variables that have been found to influence susceptibility to memory distortions, thus reducing generalizability. For example, susceptibility has been found to be associated with depression (e.g., Brennen et al., 2007; Johnson et al., 1993), trait dissociation (e.g., Clancy et al., 2000), and level of arousal (Corson & Verrier, 2007), among other factors (see Loftus & Davis, 2006 for a review). Levels of distress and arousal elicited by the film clip used in our study are clearly not comparable to those elicited by real-life (traumatic) events. Furthermore, we know that susceptibility to memory distortions through misinformation increases as more time passes between the original event and the introduction of misinformation (e.g., Loftus et al., 1978). In our study, the ImRs intervention took place only one day after the memory of the film clip was induced. Although we attempted to take into account the influence of the strength of the original memory by manipulating it experimentally, we cannot exclude the possibility that different memory effects of ImRs would be observed if applied after a longer time interval. Furthermore, in order to avoid experimentally induced interference with memory, we did not perform a pre-intervention check on memory clarity for the film clip. This decision aligns with memory reconsolidation theory, which suggests that any memory reactivation could impact subsequent reconsolidation (Nader et al., 2000; Kindt 2018). However, a pilot phase manipulation check confirmed our experimental manipulation's success. Participants exposed to the unclear film clip exhibited lower memory confidence, provided fewer correct answers, and gave more incorrect and "I don't know" responses than those exposed to the clear film clip (detailed pilot data can be assessed on OSF under supplements). The main study results also support our intended manipulation, showing a significant memory clarity effect across all memory accuracy measures. However, future studies could additionally assess subjective memory clarity post-memory induction using a brief self-report measure to avoid triggering reconsolidation.

Third, we used an experimental version of ImRs that has been adjusted to the online study design in that the intervention was delivered via audiotape. The high vividness ratings indicate that participants could nevertheless imagine the script well (see Table S2 in the Supplemental Material). However, we do not know whether some participants would have executed the imagery task even better had it been delivered by an experimenter. Moreover, due to the sample and the memory induction, we used a standardized and stripped-down intervention protocol (e.g., no switch between adult and child perspectives). Although, with regard to the potential memory distortion (our main variable of interest) the supposed core aspects of ImRs (i.e., imagery-based memory reactivation and modification) were included, we can not rule out that we would have found different effects had we used a more naturalistic ImRs script. For example, in the clinical context, ImRs involves interactions between therapist and patient which might leave more room for suggestive processes that might affect memory accuracy. Note, however, that earlier studies that used personalized ImRs scripts delivered in a laboratory setting which involved interactions between participants and experimenter also did not find reduced memory accuracy after ImRs (Ganslmeier et al., 2022, 2023).

Fourth, while repeated retrieval typically enhances memory (Roediger & Butler, 2011), it has also been shown that it can enhance susceptibility to memory distortion in the context of misinformation (Heaps & Nash, 2001; Henkel, 2004). Moreover, repeated exposure to misinformation was found to increase the misinformation effect (Foster et al., 2012). As we only used one short ImRs session, we cannot draw conclusions about the memory effects of repeated ImRs (but see Ganslmeier et al., 2022 who found no memory deterioration, even when participants were instructed to repeatedly listen to recordings of the ImRs between sessions).

Fifth, like previous studies assessing the effects of ImRs on memory accuracy, we only examined whether the memory of the original event details was worse after ImRs than it had been before. During ImRs, the changes that are introduced to the memory are typically very salient and often involve major alterations to the course of events. For example, a new helpful figure might be introduced to the re-imagined scene and confront the perpetrator. However, less significant details from the original memory, such as what people were wearing, are generally considered clinically irrelevant and are thus not intentionally modified during ImRs. Nevertheless, it is conceivable that the memory of specific details of the original event might be affected by subtle processes that could occur during ImRs, even if those details are not intentionally altered. We were therefore particularly interested in determining whether simply instructing individuals to vividly imagine changes to their memory, as is typically done in clinical practice, would suffice to distort the original memory, especially for individuals with an unclear original memory. Future studies should additionally investigate whether counterfactual details introduced during the rescripting phase are later erroneously accepted or incorporated into memory reports (e.g., Reineck et al., 2023). Note, however, that future studies should keep in mind what type of changes introduced in ImRs are clinically relevant and are therefore worth testing for their potential to induce false memories.

Finally, we only used a memory recognition task to assess memory accuracy which might limit the generalizability of our findings. Given that trauma survivors who serve as eye witnesses in criminal proceedings are often asked to provide a detailed verbal report of the event as part of their testimony, using a free recall task in addition to a memory recognition task might improve external validity and generalizability. In addition, as free recall and memory recognition tasks involve different cognitive processes, results from memory recognition tasks and free recall tasks can differ (e.g., Malloggi et al., 2022), which stresses the importance of assessing the effects of ImRs on memory accuracy across different memory measures. Although earlier studies using a free recall task found consistent results in that participants who received ImRs reported more correct details in both the memory recognition task and the free recall task (Ganslmeier et al., 2022, 2023), we do not know if our findings would replicate across different memory measures.

Implications

When using ImRs to target aversive memories in clinical contexts, the main concern is reducing memory distress as well as symptoms of psychopathology. The effects of the intervention on memory accuracy only play a secondary role. However, memory accuracy can become critical in other contexts of a patient's life where correct recall of the historic facts is necessary. This is especially true for trauma survivors who may need to testify in legal cases. Concerns about the potential adverse impact on memory accuracy of interventions targeting aversive memories, such as ImRs, can then significantly affect the assessment of the victim's credibility in court (Gasch, 2018; Schemmel & Volbert, 2021). As a result, patients are often advised both by legal and psychological professionals to delay the beginning of trauma-focused psychological treatment until legal proceedings conclude (Bublitz, 2020; but see also different recommendations, for example the updated legal guidance on pre-trial therapy in the UK which explicitly states that therapy should not be delayed, The Crown Prosecution Service, 2022). Affected patients are therefore confronted with the dilemma of whether they should prioritize their health by seeking therapy or their credibility as witnesses. However, our results together with previous studies challenge these concerns and suggest that ImRs neither necessarily nor typically leads to memory distortion.

Nevertheless, more systematic research is needed to investigate any factors that could potentially increase the risk of memory distortion through imagery-based psychological interventions in order to minimize the risks of memory distortion through psychological interventions and of denying patients from receiving appropriate treatment. In addition, future studies should also assess the effects of ImRs on the accuracy of real-life autobiographical memories in clinical samples. Note, however, that for memories of naturalistic events that are beyond experimental control, only approximations for memory accuracy, such as consistency of memory recall, must be used, which in turn limits the validity of such studies with regard to memory accuracy.

Conclusion

In sum, our findings provide a valuable contribution to the current debate on potential adverse side effects of imagery-based psychological interventions like ImRs on memory accuracy. Our study expands earlier research that challenged concerns about potential memory distortions through ImRs by adopting a novel methodological approach which allowed us to specify the conditions under which ImRs may (or may not) lead to memory distortions. We could demonstrate that ImRs, does not distort memory – not even with a sensory-perceptual instruction focus, as typically provided in clinical practice. Further, by experimentally manipulating the quality of the original memory, we could account for (some of the) typical memory characteristics found in patients who receive psychological treatment (i.e., weak original memories due to forgetting with the passage of time or due to dysfunctional memory processes, e.g., dissociation). Our data indicate that even in cases of unclear and incomplete original memories, encouraging patients to form vivid images during the intervention does not pose a particular risk with regard to memory accuracy and may even improve memory accuracy. Although these findings are very gratifying from a clinical-therapeutic point of view, future research is needed to systematically investigate potential risk factors that might lead ImRs to distort factual event memory.

Transparency

Conflict of interest

MA, AM, TE, and LW have no conflicts of interest to disclose.

Author contributions

Conceptualization: M. Aleksic, L. Wolkenstein, T. Ehring; Methodology: M. Aleksic, A. Reineck, L. Wolkenstein, T. Ehring; Software (Online-Platform for experimental design): M. Aleksic, A. Reineck; Investigation: M. Aleksic;

Project administration: M. Aleksic; Formal analysis: A. Reineck; Writing – original draft: M. Aleksic, A. Reineck; Writing – review and editing: M. Aleksic, A. Reineck, L. Wolkenstein, T. Ehring; Visualization: A. Reineck; Supervision: L. Wolkenstein, T. Ehring. All authors approved the final version of the manuscript for submission.

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Preregistration

The hypotheses, study design and analysis plan of this study were preregistered at the Open Science Framework (https://osf.io/j9f85).

Data Availability Statement

Anonymized data, codes and study materials have been made publicly available via the Open Science Framework and can be accessed at https://osf.io/j9f85/. The design and analysis plan for the experiment were preregistered at OSF and can be accessed at https://osf.io/j9f85/.

Ethical approval

The study was carried out in accordance with the provisions of the World Medical Association Declaration of Helsinki and approved by the local Research Ethics Committee of the Department of Psychology at LMU Munich (17_Ehring_b). All participants provided written informed consent.

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Supplemental Material

The online version contains supplementary material.

References Study II

Ackil, J. K., & Zaragoza, M. S. (1998). Memorial consequences of forced confabulation: age differences in susceptibility to false memories. *Developmental Psychology*, *34*(6), 1358–1372. https://doi.org/10.1037/0012-1649.34.6.1358

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). https://doi.org/10.1176/appi.books.9780890425596

Arntz, A. (2012). Imagery Rescripting as a Therapeutic Technique: Review of Clinical Trials, Basic Studies, and Research Agenda. *Journal of Experimental Psychopathology*, *3*(2), 189–208. https://doi.org/10.5127/jep.024211

Arntz, A., & Weertman, A. (1999). Treatment of childhood memories: Theory and practice. *Behaviour Reserch and Therapy*, *37*, 715–740.

Beckers, T., & Kindt, M. (2017). Memory Reconsolidation Interference as an Emerging Treatment for Emotional Disorders: Strengths, Limitations, Challenges, and Opportunities. *Annual Review of Clinical Psychology*, *13*(1), 99–121. https://doi.org/10.1146/annurev-clinpsy-032816-045209

Billings, F. J., Hyman, I. E., & Husband, T. H. (1995). False memories of childhood experiences. *Applied Cognitive Psychology*, *9*(September 1994), 181–197. internal-pdf:/hyman et al (1995) false memories of childhood experiences.pdf

Blank, H., & Launay, C. (2014). How to protect eyewitness memory against the misinformation effect: A meta-analysis of post-warning studies. *Journal of Applied Research in Memory and Cognition*, *3*(2), 77–88. https://doi.org/10.1016/j.jarmac.2014.03.005

Boterhoven De Haan, K. L., Lee, C. W., Fassbinder, E., Van Es, S. M., Menninga, S., Meewisse, M. L., Rijkeboer, M., Kousemaker, M., & Arntz, A. (2020). Imagery rescripting and eye movement desensitisation and reprocessing as treatment for adults with post-traumatic stress disorder from childhood trauma: Randomised clinical trial. *British Journal of Psychiatry*, *217*(5), 609–615. https://doi.org/10.1192/bjp.2020.158

Bradley, M., & Lang, P. J. (1994). Self-Assessment Manikin (SAM). *J.Behav.Ther. & Exp. Psychiat.*, *25*(1), 49–59.

Brennen, T., Dybdahl, R., & Kapidžić, A. (2007). Trauma-related and neutral false memories in war-induced Posttraumatic Stress Disorder. *Consciousness and Cognition*, *16*(4), 877–885. https://doi.org/10.1016/j.concog.2006.06.012

Brewin, C. R. (2006). Understanding cognitive behaviour therapy: A retrieval competition account. *Behaviour Research and Therapy*, *44*(6), 765–784. https://doi.org/10.1016/j.brat.2006.02.005

Brewin, C. R., & Andrews, B. (2017). Creating Memories for False Autobiographical Events in Childhood: A Systematic Review. *Applied Cognitive Psychology*, *31*(1), 2–23. https://doi.org/10.1002/acp.3220

Brewin, C. R., Gregory, J. D., Lipton, M., & Burgess, N. (2010). Intrusive Images in Psychological Disorders: Characteristics, Neural Mechanisms, and Treatment Implications. *Psychological Review*, *117*(1), 210–232. https://doi.org/10.1037/a0018113

Brooks, M., Bolker, B., Kristensen, K., Maechler, M., Magnusson, A., McGillycuddy, M., ... Stouffer, D. B. (2023). *glmmTMB: Generalized Linear Mixed Models using Template Model Builder* (Version 1.1.8). https://github.com/glmmTMB/glmmTMB

Bublitz, C. (2020). Health or credibility? Overcoming the dilemma of trauma therapy. *Ethik in Der Medizin*. https://doi.org/10.1007/s00481-019-00560-3

Clancy, S. A., Schacter, D. L., McNally, R. J., & Pitman, R. K. (2000). False recognition in women reporting recovered memories of sexual abuse. *Psychological Science*, *11*(1), 26–31. https://doi.org/10.1111/1467-9280.00210

Corson, Y., & Verrier, N. (2007). Emotions and False Memories. *Psychological Science, 18*(3), 208–211. https://doi.org/10.1111/j.1467-9280.2007.01874.x

Craik, F. I., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. Journal of verbal learning and verbal behavior, 11(6), 671-684.

Crown Prosecution Service. (2022). *Pre-Trial Therapy. Legal Guidance.* https://www.cps.gov.uk/legal-guidance/pre-trial-therapy

Davis, D., & Loftus, E. F. (2020). Recovered memories and false memories. *New Oxford Textbook of Psychiatry*, *August*, 884–894. https://doi.org/10.1093/med/9780198713005.003.0085

Dibbets, P., & Arntz, A. (2016). Imagery rescripting: Is incorporation of the most aversive scenes necessary? *Memory*, *24*(5), 683–695. https://doi.org/10.1080/09658211.2015.1043307

Foster, J. L., Huthwaite, T., Yesberg, J. A., Garry, M., & Loftus, E. F. (2012). Repetition, not number of sources, increases both susceptibility to misinformation and confidence in the accuracy of eyewitnesses. *Acta Psychologica*, *139*(2), 320–326. https://doi.org/10.1016/j.actpsy.2011.12.004

Fox, J., & Weisberg, S. (2019). *An R Companion to Applied Regression* (Third edition). Sage. https://socialsciences.mcmaster.ca/jfox/Books/Companion/

Ganslmeier, M., Kunze, A. E., Ehring, T., & Wolkenstein, L. (2022). The dilemma of trauma-focused therapy: effects of imagery rescripting on voluntary memory. *Psychological Research, 0123456789*. https://doi.org/10.1007/s00426-022-01746-z

Ganslmeier, M., Ehring, T., & Wolkenstein, L. (2023). Effects of imagery rescripting and imaginal exposure on voluntary memory. Behaviour Research and Therapy, 170, 104409.

Garry, M., Manning, C. G., Loftus, E. F., & Sherman, S. J. (1996). Imagination inflation: Imagining a childhood event inflates confidence that it occurred. *Psychonomic Bulletin and Review*, *3*(2), 208–214. https://doi.org/10.3758/BF03212420

Gasch, U. (2018). Psychotherapie vor Abschluss der Beweisaufnahme im Strafverfahren ? *Kriminalistik*, *12*(March).

Goff, L. M., & Roediger, H. L. (1998). Imagination inflation for action events: Repeated imaginings lead to illusory recollections. *Memory and Cognition*, *26*(1), 20–33. https://doi.org/10.3758/BF03211367

Golkar, A., Tjaden, C., & Kindt, M. (2017). Vicarious extinction learning during reconsolidation neutralizes fear memory. *Behaviour Research and Therapy*. https://doi.org/10.1016/j.brat.2017.02.004

Gräfe, K., Zipfel, S., Herzog, W., & Löwe, B. (2004). Screening psychischer störungen mit dem "Gesundheitsfragebogen für Patienten (PHQ-D)". Ergebnisse der Deutschen validierungsstudie. *Diagnostica*, *50*(4), 171–181. https://doi.org/10.1026/0012-1924.50.4.171

Greene, E., Flynn, M. S., & Loftus, E. F. (1982). Inducing resistance to misleading information. *Journal of Verbal Learning and Verbal Behavior*, *21*(2), 207–219. https://doi.org/10.1016/S0022-5371(82)90571-0

Hackmann, A., Ehlers, A., Speckens, A., & Clark, D. M. (2004). Characteristics and content of intrusive memories in PTSD and their changes with treatment. *Journal of Traumatic Stress*, *17*(3), 231–240. https://doi.org/10.1023/B:JOTS.0000029266.88369.fd

Hagenaars, M. A., & Arntz, A. (2012). Reduced intrusion development after post-trauma imagery rescripting; An experimental study. *Journal of Behavior Therapy and Experimental Psychiatry*, *43*(2), 808–814. https://doi.org/10.1016/j.jbtep.2011.09.005

Heaps, C. M., & Nash, M. (2001). Comparing Recollective Experience in True and False Autobiographical Memories. *Journal of Experimental Psychology: Learning Memory and Cognition*, *27*(4), 920–930. https://doi.org/10.1037/0278-7393.27.4.920

Henkel, L. A. (2004). Erroneous memories arising from repeated attempts to remember. *Journal of Memory and Language*, *50*(1), 26–46. https://doi.org/10.1016/j.jml.2003.08.001

Hermanutz, M., & Schröder, J. (2015). Leitfaden zur Vernehmung vonZeugen und Beschuldigten mit Vernehmungskarten. *Hochschule Hannover.*, *148*, 148–162.

Holmes, E. A., Arntz, A., & Smucker, M. R. (2007). Imagery rescripting in cognitive behaviour therapy: Images, treatment techniques and outcomes. *Journal of Behavior Therapy and Experimental Psychiatry*, *38*(4), 297–305. https://doi.org/10.1016/j.jbtep.2007.10.007

Holmes, E. A., & Mathews, A. (2010). Mental imagery in emotion and emotional disorders. *Clinical Psychology Review*, *30*(3), 349–362. https://doi.org/10.1016/j.cpr.2010.01.001

Howe, M. L., Wimmer, M. C., Gagnon, N., & Plumpton, S. (2009). An associative-activation theory of children's and adults' memory illusions. *Journal of Memory and Language*, *60*(2), 229–251. https://doi.org/10.1016/j.jml.2008.10.002

Hyman, I. E., & Pentland, J. (1996). The role of mental imagery in the creation of false childhood memories. *Journal of Memory and Language*, *35*(2), 101–117. https://doi.org/10.1006/jmla.1996.0006

James, E. L., Bonsall, M. B., Hoppitt, L., Tunbridge, E. M., Geddes, J. R., Milton, A. L., & Holmes, E. A. (2015). Computer Game Play Reduces Intrusive Memories of Experimental Trauma via Reconsolidation-Update Mechanisms. *Psychological Science*, *26*(8), 1201–1215. https://doi.org/10.1177/0956797615583071

James, E. L., Lau-zhu, A., Clark, I. A., Visser, R. M., Hagenaars, M. A., & Holmes, E. A. (2016). The trauma fi lm paradigm as an experimental psychopathology model of psychological trauma : intrusive memories and beyond. *Clinical Psychology Review*, *47*, 106–142. https://doi.org/10.1016/j.cpr.2016.04.010

Johnson, M. K., Foley, M. A., Suengas, A. G., & Raye, C. L. (1988). Phenomenal Characteristics of Memories for Perceived and Imagined Autobiographical Events. *Journal of Experimental Psychology: General*, *117*(4), 371–376. https://doi.org/10.1037/0096-3445.117.4.371

Johnson, M. K., Hashtroudi, S., & Lindsay, D. S. (1993). Source monitoring. In *Psychological Bulletin* (Vol. 114, Issue 1, pp. 3–28). https://doi.org/10.1037//0033-2909.114.1.3

Karanian, J. M., Rabb, N., Wulff, A. N., Torrance, M. G., Thomas, A. K., & Race, E. (2020). Protecting memory from misinformation: Warnings modulate cortical reinstatement during memory retrieval. *Proceedings of the National Academy of Sciences of the United States of America*, *117*(37), 22771–22779. https://doi.org/10.1073/pnas.2008595117

Kassambara, A. (2023a). *ggpubr: 'ggplot2' Based Publication Ready Plots* (Version 0.6.0). https://rpkgs.datanovia.com/ggpubr/

Kassambara, A. (2023b). *rstatix: Pipe-Friendly Framework for Basic Statistical Tests* (Version 0.7.2). https://rpkgs.datanovia.com/rstatix/

Kelley, K. (2023). *MBESS: The MBESS R Package* (Version 4.9.3). https://www3.nd.edu/~kkelley/site/MBESS.html

Koch, P. (Director). (2010). *Picco.* [Film]. Philipp Worm, & Tobias Walker.

Kroenke, K., Spitzer, R. L., & Williams, J. B. W. (2002). *The PHQ-9: Validity of a Brief Depression Severity Measure*. *64*(2), 258–266.

Krohne, H. W., Egloff, B., Kohlmann, C. W., & Tausch, A. (1996). Untersuchungen mit einer deutschen Version der Positive and Negative Affect Schedule (PANAS) [Investi- gations with a German version of the Positive and Negative Affect Schedule (PANAS)]. *Diagnostica*, 42, 139-156.

Kunze, A. E., Arntz, A., Morina, N., Kindt, M., & Lancee, J. (2017). Efficacy of imagery rescripting and imaginal exposure for nightmares: A randomized wait-list controlled trial. *Behaviour Research and Therapy*, *97*, 14–25. https://doi.org/10.1016/j.brat.2017.06.005

Laux, L., Glanzmann, P., Schaffner, P., & Spielberger, C. (1981). *Das State-Trait-Angstinventar*. Theoretische Grundlagen und Handanweisung. Weinheim: Beltz Test.

Lau-Zhu, A., Henson, R. N., & Holmes, E. A. (2019). Intrusive Memories and Voluntary Memory of a Trauma Film: Differential Effects of a Cognitive Interference Task After Encoding. In *Journal of Experimental Psychology: General*. https://doi.org/10.1037/xge0000598

Leding, J. K., & Antonio, L. (2019). Need for cognition and discrepancy detection in the misinformation effect. *Journal of Cognitive Psychology*, *31*(4), 409–415. https://doi.org/10.1080/20445911.2019.1626400

Lee, J. L. C. (2009). Reconsolidation: maintaining memory relevance. *Trends in Neurosciences*, *32*(8), 413–420. https://doi.org/10.1016/j.tins.2009.05.002

Lindsay, D. S., & Johnson, M. K. (2000). False memories and the source monitoring framework: Reply to Reyna and Lloyd (1997). *Learning and Individual Differences*, *12*(2), 145–161. https://doi.org/10.1016/S1041-6080(01)00035-8

Loftus, E. F. (1975). Leading Questions and the Eyewitness Report. *Cognitive Psychology*, *7*(4), 560–572.

Loftus, E. F. (1992). When A Lie Becomes Memory's Truth: Memory Distortion After Exposure to Misinformation. *Current Directions in Psychological Science*, *1*(4), 121–123. https://doi.org/10.1111/1467-8721.ep10769035

Loftus, E. F. (1997). Creating False Memories. *Scientific American 277 (3), 70-75.*, *277*(3), 70–75.

Loftus, E. F. (2005). Planting misinformation in the human mind: A 30-year investigation of the malleability of memory. *Learning and Memory*, *12*(4), 361–366. https://doi.org/10.1101/lm.94705

Loftus, E. F., & Davis, D. (2006). Recovered memories. *Annual Review of Clinical Psychology*, *2*, 469–498. https://doi.org/10.1146/annurev.clinpsy.2.022305.095315

Loftus, E. F., & Klemfuss, J. Z. (2023). Misinformation–past, present, and future. *Psychology, Crime and Law*. https://doi.org/10.1080/1068316X.2023.2219813

Loftus, E. F., Miller, D. G., & Burns, H. J. (1978). Semantic integration of verbal information into a visual memory. *Journal of Experimental Psychology: Human Learning and Memory*, *4*(1), 19–31. https://doi.org/10.1037/0278-7393.4.1.19

Lyle, K. B., & Johnson, M. K. (2007). Source misattributions may increase the accuracy of source judgments. *Memory and Cognition*, *35*(5), 1024–1033. https://doi.org/10.3758/BF03193475

Monfils, M. H., Cowansage, K. K., Klann, E., & Ledoux, J. E. (2009). Extinction-Reconsolidation boundaries: Key to persistent attenuation of fear memories. *Science*, *324*(5929), 951–955. https://doi.org/10.1126/science.1167975

Morina, N., Lancee, J., & Arntz, A. (2017). Imagery rescripting as a clinical intervention for aversive memories: A meta-analysis. *Journal of Behavior Therapy and Experimental Psychiatry*, *55*, 6–15. https://doi.org/10.1016/j.jbtep.2016.11.003

Nader, K., Schafe, G. E., & Le Doux, J. E. (2000). The labile nature of consolidation theory. *Nature*, *406*(December), 722–726.

Nader, K., & Hardt, O. (2009). A single standard for memory: the case for reconsolidation. Nature Reviews Neuroscience, 10(3), 224-234.

Nori, R., Bensi, L., Gambetti, E., & Giusberti, F. (2014). Individual differences in the Enhanced Cognitive Interview: the role of imagery. *Psychology, Crime and Law*, *20*(9), 833–851. https://doi.org/10.1080/1068316X.2014.885968

Otgaar, H., Houben, S. T. L., Rassin, E., & Merckelbach, H. (2021). Memory and eye movement desensitization and reprocessing therapy: a potentially risky combination in the courtroom. *Memory*, *29*(9), 1254–1262. https://doi.org/10.1080/09658211.2021.1966043

Özbek, M., Bohn, A., & Berntsen, D. (2017). Imagining the personal past: Episodic counterfactuals compared to episodic memories and episodic future projections. *Memory and Cognition*, *45*(3), 375–389. https://doi.org/10.3758/s13421-016-0671-2

R Core Team (2023). _R: A Language and Environment for Statistical Computing_. R Foundation forStatistical Computing, Vienna, Austria. <https://www.R-project.org/>.

Raabe, S., Ehring, T., Marquenie, L., Olff, M., & Kindt, M. (2015). Imagery Rescripting as stand-alone treatment for posttraumatic stress disorder related to childhood abuse. *Journal of Behavior Therapy and Experimental Psychiatry*, *48*, 170–176. https://doi.org/10.1016/j.jbtep.2015.03.013

Rattel, J. A., Grünberger, L. M., Reichenberger, J., Liedlgruber, M., Miedl, S. F., Blechert, J., & Wilhelm, F. H. (2019). Frequency of Intrusions and Appraisal of Related Distress After Analogue Trauma: A Comparative Ecological Momentary Assessment Methods Study. *Cognitive Therapy and Research, 43*(1), 174–184.

Revelle, W. (2023). *psych: Procedures for Psychological, Psychometric, and Personality Research* (Version 2.3.12). Northwestern University, Evanston, Illinois. https://CRAN.R-project.org/package=psych

Roediger, H. L., & Butler, A. C. (2011). The critical role of retrieval practice in long-term retention. *Trends in Cognitive Sciences*, *15*(1), 20–27. https://doi.org/10.1016/j.tics.2010.09.003

Schemmel, J., & Volbert, R. (2021). Therapy or Credibility? - Psychotherapy during ongoing criminal proceedings. *Report Psychologie, 46,* 14-24.

Schiller, D., Monfils, M. H., Raio, C. M., Johnson, D. C., Ledoux, J. E., & Phelps, E. A. (2010). Preventing the return of fear in humans using reconsolidation update mechanisms. *Nature*, *463*(7277), 49–53. https://doi.org/10.1038/nature08637

Seamon, J. G., Philbin, M. M., & Harrison, L. G. (2006). Do you remember proposing marriage to the Pepsi machine? False recollections from a campus walk. *Psychonomic Bulletin and Review*, *13*(5), 752–756. https://doi.org/10.3758/BF03193992

Sevenster, D., Beckers, T., & Kindt, M. (2012). Instructed extinction differentially affects the emotional and cognitive expression of associative fear memory. *Psychophysiology*, *49*(10), 1426–1435. https://doi.org/10.1111/j.1469-8986.2012.01450.x

Sharman, S. J., & Scoboria, A. (2009). Imagination Equally Influences False Memories of High and Low Plausibility Events. *Applied Cognitive Psychology*, *23*(6), 813–827. https://doi.org/10.1002/acp.1515

Siegesleitner, M., Strohm, M., Wittekind, C. E., Ehring, T., & Kunze, A. E. (2019). Effects of imagery rescripting on consolidated memories of an aversive film. *Journal of Behavior Therapy and Experimental Psychiatry*, *62*, 22–29. https://doi.org/10.1016/j.jbtep.2018.08.007

Simmons, J. P., Nelson, L. D., & Simonsohn, U. (2011). *False-Positive Psychology : Undisclosed Flexibility in Data Collection and Analysis Allows Presenting Anything as Significant*. *22*(11), 1359–1366. https://doi.org/10.1177/0956797611417632

Smucker, M. R., Dancu, C., Foa, E. B., & Niederee, J. L. (1995). Imagery Rescripting: A New Treatment for Survivors of Childhood Sexual Abuse Suffering From Posttraumatic

Stress. *Journal of Cognitive Psychotherapy*, *9*(1), 3–17. http://www.ingentaconnect.com/content/springer/jcogp/1995/00000009/00000001/art00001

Soeter, M., & Kindt, M. (2010). Dissociating response systems: Erasing fear from memory. *Neurobiology of Learning and Memory*, *94*(1), 30–41. https://doi.org/10.1016/j.nlm.2010.03.004

Spielberger, C. D., Gorsuch, R. L., & Lushene, R. (1970). *Manual for the State-Trait Anxiety Inventory*. Palo Alto, CA: Consulting Psychologists Press.

Steiger, J. H. (2004). Beyond the F test: Effect size confidence intervals and tests of close fit in the analysis of variance and contrast analysis. *Psychological Methods*, *9*(2), 164–182. https://doi.org/10.1037/1082-989X.9.2.164

Strohm, M., Siegesleitner, M., Kunze, A. E., Ehring, T., & Wittekind, C. E. (2019). Imagery Rescripting of Aversive Autobiographical Memories: Effects on Memory Distress, Emotions, and Feelings of Mastery. *Cognitive Therapy and Research*, *43*(6), 1005–1017. https://doi.org/10.1007/s10608-019-10021-2

Thomas, A. K., Bulevich, J. B., & Loftus, E. F. (2003). Exploring the role of repetition and sensory elaboration in the imagination inflation effect. *Memory and Cognition*, *31*(4), 630–640. https://doi.org/10.3758/BF03196103

Thomas, A. K., & Loftus, E. F. (2002). Creating bizarre false memories through imagination. *Memory and Cognition*, *30*(3), 423–431. https://doi.org/10.3758/BF03194942

Tousignant, J. P., Hall, D., & Loftus, E. F. (1986). Discrepancy detection and vulnerability to misleading postevent information. *Memory & Cognition*, *14*(4), 329–338. https://doi.org/10.3758/BF03202511

Wickham, H., Chang, W., Henry, L., Pedersen, T. L., Takahashi, K., Wilke, C., ... Posit, PBC. (2023). *ggplot2: Create Elegant Data Visualisations Using the Grammar of Graphics* (Version 3.4.4). https://ggplot2.tidyverse.org

Wickham, H., François, R., Henry, L., Müller, K., Vaughan, Posit Software, PBC. (2023). dplyr: A Grammar of Data Manipulation (Version 1.1.4) [Software]. R Project. https://dplyr.tidyverse.org

Wilke, C. O. (2023). *cowplot: Streamlined Plot Theme and Plot Annotations for 'ggplot2'* (Version 1.1.2). https://wilkelab.org/cowplot/

4 Study III

Selective Effects of Eye Movement Desensitization and Reprocessing, Imagery Rescripting and Imaginal Exposure on Voluntary and Involuntary Memory of an Aversive Autobiographical Avent

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The study was pre-registered (https://osf.io/ekyvm). Data, R-Code and materials have been made available online (https://osf.io/3s9b4/).

Abstract

This study examined the selective effects of three trauma-focused interventions – Eye Movement Desensitization and Reprocessing (EMDR), Imagery Rescripting (ImRs), and Imaginal Exposure (IE) – on voluntary and involuntary memories of an aversive autobiographical event in a healthy sample (*N* = 182). Participants completed a free recall task in the first session and then received either ImRs, IE, EMDR, or no intervention (NIC). One week later, they repeated the free recall task. Changes in memory quality (disorganization and coherence) and consistency were assessed by independent raters. Involuntary memory was assessed using an app-based intrusion diary during the week before and after the intervention. Additionally, psychophysiological reactivity to intrusive memories was measured during an intrusion-sampling period conducted in the laboratory in both experimental sessions. In terms of voluntary memory, IE was associated with a reduction in disorganized thoughts, while EMDR and ImRs increased contextual memory coherence. Importantly, none of the interventions led to an increase in contradictions or omissions compared to NIC, challenging concerns about the potential of these interventions to distort voluntary memory. With regard to involuntary memory, all interventions effectively reduced intrusion load, while only ImRs significantly reduced the number of intrusions compared to NIC. No group differences were observed in the reduction of psychophysiological responses to intrusions between sessions. These findings suggest that EMDR, ImRs, and IE can selectively reduce distressing intrusions without compromising voluntary memory. Further research is needed to replicate these effects in clinical populations.

Introduction

Aversive emotional memories of a traumatic event are a hallmark symptom of posttraumatic stress disorder (PTSD; APA, 2013). Vivid, involuntary recollections of trauma fragments (i.e., intrusions) are often described as the most distressing symptom for patients suffering from PTSD (Ehlers et al., 2004; Holmes & Mathews, 2010). However, as outlined by Lau-Zhu et al. (2019), despite the significant distress caused by trauma memories, the aim of psychological interventions is not to erase them entirely. In fact, there are numerous scenarios where deliberate remembering of a traumatic event is necessary (e.g., for witness statements in criminal proceedings) or even essential for survival (i.e., informing future danger assessment). Moreover, several influential theories on PTSD highlight that poor voluntary memory – i.e., intentionally and consciously retrieved memory – of traumatic events, reflected in fragmented, disorganized or coherence-lacking memory recall, plays a critical role in the development and maintenance of the disorder (e.g., Brewin, 2007; Ehlers et al., 2004; Foa et al., 1995; although this has been a topic of debate, see e.g., Rubin et al., 2016). Therefore, trauma-focused interventions aim to selectively reduce uncontrollable and involuntary memories of the traumatic event, but at the same time to preserve or even promote voluntary recall of the trauma (Lau-Zhu et al., 2019).

A series of experimental studies have demonstrated that it is indeed possible to selectively influence specific aspects of aversive memories, such as their emotional valence or their involuntary occurrence, without impacting other aspects, such as declarative knowledge of the aversive event. These effects have been observed using pharmacological interventions (e.g., Kindt et al., 2009; Sevenster et al., 2013) and behavioral tasks (e.g., Golkar et al., 2017; Lau-Zhu et al., 2019). However, it remains unclear whether clinically established trauma-focused interventions similarly have differential effects on voluntary versus involuntary memories. There is good evidence that trauma-focused interventions effectively reduce the occurrence of involuntary, intrusive trauma memories (e.g., Cusack et al., 2015; Kip et al., 2023; Watts et al., 2013). However, their impact on voluntary memory is less clear (Visser et al., 2018).

Predictions by clinical theories regarding intervention effects on voluntary memory

Clinical theories of PTSD propose that trauma-focused interventions should *improve* voluntary memory recall. For example, Brewin's dual representation theory (Brewin et al., 1996, 2010) posits that traumatic experiences form two types of memory representations: (a) contextualized representations (C-reps), which are voluntarily retrievable and integrated into autobiographical memory, and (b) sensory-bound representations (S-reps), which are low-level, sensation-based memories that are involuntarily triggered (Brewin, 2014; Brewin et al., 2010). The theory suggests that a dissociation between these memory representations leads to poorly elaborated and contextualized trauma memories. This may be responsible for the observation that voluntarily recalled trauma memories are of poor quality (i.e., incoherent and disorganized) and that intrusive memories are triggered involuntarily (activation of S-reps) in PTSD (Brewin, 2014; 2010). Trauma-focused interventions, such as Imaginal Exposure (IE), Eye Movement Desensitization and Reprocessing (EMDR), and Imagery Rescripting (ImRs), should help to integrate these dissociated memory representations based on this model.

In IE (Foa et al., 1999), patients repeatedly relive their traumatic memory in their imagination until the distress declines. In EMDR (Shapiro, 2017), memory reactivation is combined with horizontal eye-movements (or other forms of bi-lateral stimulation such as tapping or listening to beeps) which was found to reduce the emotional intensity and vividness of the reactivated memory (Houben et al., 2020; Van Den Hout et al., 2001). In ImRs (Arntz & Weertman, 1999), patients are asked to reactivate their memory in the imagination and to subsequently change the course of events into a desired direction (e.g., a helping figure enters the scene, confronts the perpetrator and takes care of the victim’s needs, e.g., Arntz &

Weertmann, 1999). According to the Dual Representation Theory, these interventions facilitate the integration of S-reps and corresponding C-reps by encouraging patients to engage intensively with their traumatic memories (i.e., revisiting the memory in detail and elaborate on the associated sensory details, emotions, cognitions, and bodily perceptions). The reduction of distress and/or memory vividness during these interventions is thought to allow patients to focus more effectively on previously avoided memory aspects. This is believed to improve voluntary access to trauma memory representations which ultimately leads to both more detailed, coherent and organized voluntary memories as well as enhanced inhibitory control over involuntary retrieval (Brewin, 2014; Brewin et al., 2010).

Predictions by legal psychology regarding intervention effects on voluntary memory

In contrast to clinical theories which predict that successful treatment should *enhance* voluntary memory recall, experts in legal psychology have raised concerns that trauma-focused interventions might *impair* voluntary memory retrieval, especially memory *accuracy* (e.g., Otgaar et al., 2021). These concerns stem from experimental research demonstrating that memories are prone to errors and that in particular imagining an event ("imagination inflation effect", Garry et al., 1996) and exposure to misleading information about an event ("misinformation effect", Goff & Roediger, 1998) can distort memory. For example, studies on imagination inflation have demonstrated that imagining events can not only increase individuals' confidence in their occurrence, even when those events never actually happened (e.g., Mazzoni & Memon, 2003), but also alter existing memories of past events (e.g., Goff & Roediger, 1998; Lyle & Johnson, 2007). Similarly, misinformation studies have shown that exposure to misleading information presented in the form of doctored evidence (see e.g., Scoboria et al., 2017 for a review) or suggestive questions (e.g., Loftus, 1997) can distort existing memories (Loftus et al., 1978) or even create entire memories of events that never occurred (e.g., Mazzoni & Memon, 2003).

Against this background, concerns have been raised that trauma-focused interventions that involve imagination techniques and/or modification of memory contents, such as IE, EMDR and ImRs, might similarly distort factual memory contents (e.g., Otgaar et al., 2021). However, while the aforementioned experimental paradigms utilizing imagination and counterfactual information are invaluable for demonstrating memory fallibility, their goals and methodologies differ significantly from those of clinical interventions. Therefore, directly generalizing findings from these experimental studies to clinical practice proves inherently challenging, given the fundamental differences in the objectives and contexts in which imagination techniques and counterfactual information are applied.

Empirical evidence on intervention effects on voluntary memory

Only a small number of studies have investigated the effects of IE, EMDR and ImRs on voluntary memory. With regard to memory quality, specifically memory coherence and organization, empirical studies have only partially supported assumptions by clinical theories that these interventions should enhance these aspects. For IE, there is no consistent evidence that it improves memory organization or coherence (Bedard-Gilligan et al., 2017a; Foa et al., 1995; Van Minnen et al., 2002), and evidence that memory reorganization is a central mechanism of action is largely lacking (Cooper et al., 2017). For EMDR and ImRs, there is evidence suggesting that that they can reduce the emotional valence (ImRs: Rameckers et al., 2024) as well as the intensity and vividness (EMDR: Houben et al., 2020; ImRs: Lee & Kwon, 2013) of aversive memories. However, it remains unclear whether these changes are associated with improved memory organization and coherence (Kindt et al., 2007a; Meckling et al., 2024), as proposed by clinical theories (Brewin et al., 2010). Few studies have directly assessed the effects of these interventions on memory coherence and organization, and their findings are inconsistent. For instance, Maxfield et al. (2008) found that EMDR reduced subjective "thought clarity," potentially indicating decreased memory organization, whereas a more recent study reported no association between reductions in vividness and changes in coherence or fragmentation (Meckling et al., 2024). Similarly, the only study examining the effect of ImRs on memory (dis)organization found no effect (Kindt et al., 2007). The few studies available are further limited by methodological issues, such as reliance on single-item measures of memory quality (Maxfield et al., 2008; Meckling et al., 2024), weakening the strength of their conclusions.

Regarding intervention effects on memory accuracy, previous studies do not seem to support the claim that these interventions carry particular risk to impair memory accuracy, despite the use of imagination and, in the case of ImRs, active rescripting of memory (e.g., Aleksic et al., 2024; Ganslmeier et al., 2022, 2023; van Schie et al., 2019). On the contrary, prior evidence indicates that memory performance may actually improve following ImRs and IE (Aleksic et al., 2024; Ganslmeier et al., 2022, 2023; Hagenaars & Arntz, 2012; Reineck et al., in prep.; Siegesleitner et al., 2019). For EMDR, the findings are less clear: while some studies found impaired accuracy of factual memory content after eye movements performed during memory retrieval (Houben et al., 2018; Leer & Engelhard, 2020a), other studies failed to replicate these findings (e.g., Calvillo & Emami, 2019; Kevin van Schie & Leer, 2019). Overall, however, the informational value of previous studies assessing the effects of these interventions on memory accuracy is limited by several factors. Many studies implemented interventions immediately after memory induction (e.g., Hagenaars & Arntz, 2012; Houben et al., 2018, 2020), i.e. before memory consolidation has taken place (Stickgold, 2005). Additionally, simple stimuli such as word lists (Houben et al., 2020), video clips (Aleksic et al., 2024; Calvillo & Emami, 2019; Ganslmeier, Ehring, et al., 2023), or pictures (Leer et al., 2017; Leer & Engelhard, 2020) were often used, limiting comparability to burdening autobiographical memories in terms of their complexity, emotional salience and intensity. Previous studies on EMDR further complicate interpretation by using reductionist intervention protocols focused on isolated eye movements (e.g., Calvillo & Emami, 2019; Houben et al., 2018, 2020) and assessing the effects within a misinformation paradigm – i.e., an intentionally suggestive context that does not reflect best clinical practice (but see Houben et al., 2020). Together, these limitations underscore the need for further research on intervention effects on memory accuracy.

To summarize, it remains unclear whether trauma-focused interventions such as EMDR, ImRs and IE can selectively reduce involuntary memory occurrence while preserving or even improving voluntary memory as intended. While the reduction of involuntary memories through trauma-focused interventions is well-documented, the impact on voluntary memory remains unclear. In particular, the degree to which they improve memory organization and coherence, as predicted by clinical theories, is still an open question. While first studies tentatively suggest that trauma-focused interventions like EMDR, ImRs and IE, may be wrongly suspected to reduce memory *accuracy*, we know little about how EMDR, IE and ImRs affect memory *quality* (i.e., changes in memory disorganization and coherence) and whether their effects are distinct. While it seems plausible that changes in memory vividness and emotionality as observed in EMDR and ImRs might be associated with changes in memory organization and coherence, different predictions about the direction of this effect can be made (Brewin et al., 2010; Meckling et al., 2024) and the current limited evidence does not allow firm conclusion about this effect. The present study aims to bridge this gap to better understand how trauma-focused treatments like EMDR, ImRs, and IE affect different aspects of memory.

Hypotheses

1. Hypotheses on involuntary memory

In line with previous research on the clinical efficacy of IE, EMDR, and ImRs, all interventions should reduce involuntary memory from pre- to post-assessment when compared to a No-Intervention-Control-Group (NIC). This should be reflected in:

a) A higher reduction in the total number of intrusions from pre- to post-assessment in all intervention groups when compared to NIC.

b) A higher reduction in psychophysiological responses (i.e., EMG and SCL) to involuntary memories experienced in the laboratory from pre- to post-assessment in IE, EMDR and IR when compared to NIC.

2. Hypothesis on organization and coherence of voluntary memory:

   Based on the fact that both EMDR and ImRs focus more explicitly on changing memory quality, and on previous findings regarding changes in memory quality in exposure therapy, we expected that EMDR and ImRs would affect memory organization and coherence when compared to IE and NIC, which were not expected to differ in these aspects. Given the discrepancy between theoretical considerations and the scarcity of previous empirical evidence, the direction of this particular effect was explored for EMDR and ImRs.

3. In light of concerns regarding negative effects of trauma-focused interventions on memory accuracy, we additionally assessed the effects of these interventions on memory consistency as exploratory analyses.

Methods

Participants

Several power analyses were conducted to calculate the appropriate sample size with regard to the proposed hypotheses on primary outcome measures (i.e., intrusions and memory quality). Previous clinical research has revealed large effects of IE, EMDR, and ImRs when compared to active and passive control conditions on intrusive symptom reduction in PTSD patients (e.g., Bisson et al., 2007; Morina et al., 2017). In analogue studies, the effects sizes on intrusions appear to be in the medium range (d = 0.71 for ImRs in Strohm et al., 2019; d = 0.4

- 0.8 for EMDR based on Experiment 2 and 3 in van Schie et al., 2019). Thus, assuming a medium effect size (f = 0.36) for Hypothesis 1, an a priori sample size calculation (power = 80%, alpha = .05) indicated a total sample size of 180 participants. Including 10% drop-out, it could be expected that 50 participants per condition would suffice to detect statistical differences between the four groups on involuntary memory. Despite the lack of empirical evidence with regard to the effects of IE, EMDR, and ImRs on pre- vs. post-measurements of voluntary memory, a power analysis (power = 80%, alpha = .05) based on the sample calculation of Hypothesis 1 showed that a sample size of 50 participants per group including 10 % drop-out would suffice to detect medium sized effects (f = .25) between the four conditions on voluntary memory. Thus, to adequately address the hypotheses, this study aimed to include a total sample of 200 participants (50 per group, including 10 % drop-out).

1,777 participants were recruited through advertisements in online social networks (i.e., Facebook, Instagram, student WhatsApp groups), local newspaper announcements, a public university website and at the local university campus. Exclusion criteria were (a) age below 18 or above 30, (b) current suicidality (QIDS-SR16 item 12 ≥ 2), (c) current psychological or neurological disorder, (d) history of psychosis or self-injurious behavior, (e) use of beta-blockers or other anti-hypertensive medication, (f) pregnancy, (g) drug intake up to 72 hours before testing, (h) more than three consumptions of alcohol within 24 hours before testing, (i) prior participation in one of the research group’s trauma-analogue studies. Inclusion criteria were (a) distressing life event within the past 24 months, (b) distress at the time of the event rated at least ‘7’ on a scale from ‘0’ (not distressing at all) to ‘10’ (extremely distressing), (c) distress at the time of study participation rated at least ‘4’ on the same scale, (d) recurrent memories of the life-event in the form of distressing intrusive thoughts or images, nightmares or emotional/physiological responding to reminders of the event, and (e) sufficient German language proficiency.

Based on these criteria, 922 participants were excluded in the online screening. Another 307 participants did not finish the screening questionnaire. 145 participants did not respond to the study invitation after completing the online screening. We had to exclude an additional 14 participants who fulfilled the exclusion criteria as assessed by the eligibility interview conducted in Session 1. In total, we had a sample of 182 participants who completed the study (151 females, 30 males, 1 non-binary, mean age = 23.24, SD = 3.62, range = 18 to 35, 81 % of German nationality).

Participants were randomly allocated to one of three intervention conditions (ImRs, IE, EMDR) or to a no intervention control condition (NIC). Participants received partial course credit or a monetary reimbursement (50 € for complete study participation).

Materials and Measures

All materials are available at the Open Science Framework (https://osf.io/tnkr7/).

Screening measures to establish eligibility and assess sample characteristics

Demographic questionnaire. Demographic information, including age, gender, nationality, highest level of education, and current employment or occupation, was collected to establish eligibility and obtain sample characteristics.

Health status questionnaire. A brief health questionnaire was administered to gather information about participants' sleep quality and duration, drug and alcohol consumption in the days preceding both study appointments, neurological disorders, cardiovascular diseases, and menstrual cycle (for female participants).

Depressive symptoms. Depressive symptoms were assessed with the Quick Inventory of Depressive Symptomatology (16-Item; Self-Report; QIDS-SR16, Rush et al., 1996; German translation by Roniger et al., 2015).

Trait Anxiety. The State-Trait-Anxiety-Inventory (STAI-S/T, Spielberger et al., 1970; German translation by Laux et al., 1981) was administered to assess trait and state anxiety.

Positive and Negative Affect. The Positive and Negative Affect Schedule (PANAS; German version: Krohne et al., 1996) was used to assess mood at the beginning of session 1 and session 2.

Exclusion of history of trauma. The Life Events Checklist for DSM-5 (LEC-5; Weathers et al., 2013, German version: Kuester et al., 2017) was used to assess lifetime exposure to a PTSD Criterion A traumatic event.

Symptoms of Posttraumatic Stress Disorder. The Posttraumatic Stress Disorder Checklist (PCL-5, Weathers et al., 2013; German version: Krüger-Gottschalk et al., 2017) was administered to assess symptoms of PTSD.

Manipulation Checks

Memory distress pre and post free recall task. We assessed subjective units of distress (SUD) on a scale ranging from 0 – 10 before and after the free recall task to check whether memory recall was equally distressing for participants across the experimental groups.

Memory distress and vividness after memory reactivation and intervention. To check whether memory reactivation was equally successful across groups, we assessed SUD and memory vividness on a scale ranging from 0 – 10 after memory reactivation. The same measures were assessed at the end of each intervention.

Outcome Measures

Involuntary Memory

Intrusion diary. The quantity (total number) and quality (type of memory as defined below; content of the memory; trigger situation; distress and vividness, each scored on a scale from 0 to 10) of intrusive memories was assessed using an app-based intrusion diary. Participants were instructed to register each involuntary memory of the autobiographical event in the app immediately upon occurrence. This assessment took place during the week before the intervention (baseline intrusions) and the week following the intervention. Intrusive memories were defined as spontaneously occurring involuntary memories of the autobiographical event, which could manifest as mental images, sounds, verbal thoughts, emotions, bodily sensations, or a combination of these (Zetsche et al., 2009). The daily total of intrusive memories was calculated from the diary data. The baseline period included seven full days before the first session. The post-intervention period began immediately after the first study appointment and ended seven full days later. The reduction in the total number of intrusions from pre- to post-intervention constitutes the primary outcome variable for intervention effects on involuntary memory. In addition, we exploratively assessed intervention effects on intrusion distress and intrusion load (number of intrusions weighted for their distress, (see Danböck et al., 2021; Rattel, Miedl, et al., 2019).

To improve adherence to the intrusion diary, participants were asked to report the number of intrusions they experienced each day via an app at the end of each day (see Hagenaars & Arntz, 2012 for a similar procedure). As these evening assessments were primarily introduced to improve diary adherence, only event-based entries were included in the analyses.

Following Holmes et al., (2004), subjective diary compliance was assessed at the post-study evaluation with the question: *"Please indicate how the following statement applies to you: I have often been unable/forgotten to enter my involuntary memories into the diary"* (on a visual-analogue scale from "not at all" = 0 to "very often" = 10) (cf. Holmes et al., 2004).

Lab-based intrusion assessment. In addition to the intrusion diary, we assessed psychophysiological reactivity to intrusions experienced in the laboratory as a secondary outcome variable for involuntary memory. During a 5-minute intrusion sampling period following the memory recall task, participants sat still in front of a black computer screen and indicated involuntary memory of the autobiographical event by pressing a key on the keyboard at each occurrence of an intrusion.

The physiological measurement of skin conductance response (SCR) and electromyography (EMG) as objective markers for emotional reactivity were recorded at both sessions using a 16-channel amplifier (Twente Medical Systems International [TMSi], EJ Oldenzaal, Netherlands) and the recording software package Polybench 1.30 (TMSi) with a sampling rate of 1024 Hz. A wet band on the non-dominant wrist served as grounding for all channels.

For the EMG, the facial muscle activity of the m. corrugator supercilii was measured as an indicator of negative valence of participants' emotional state accompanying intrusions expressed in the face (Mauss & Robinson, 2009). A pair of Ag/AgCl electrodes with an inner diameter of 2mm, filled with EMG gel, was used. After cleaning the skin with Nuprep peeling gel and alcohol pads, electrodes were attached with adhesive rings and placed one centimeter above the participants' left eyebrow.

The electrodermal activity (EDA) was recorded by applying a constant voltage (0.5 V) between the middle phalanges of the ring and middle fingers of the non-dominant hand, using a pair of Ag/AgCl electrodes with a 5 mm inner diameter, filled with isotonic paste (TD-246, MedCat, Germany). Electrodes were attached to the skin using adhesive rings and medical tape. The phasic skin conductance response (SCR, in µS) was used as a measure of sympathetic arousal in response to involuntary memory (Mauss & Robinson, 2009). Fluctuations with an increase of more than 0.02 µS were considered a response (Boucsein, 2012).

The physiological measures were preprocessed using the Autonomic Nervous System Laboratory (ANSLAB) software version 2.6 (Blechert, et al., 2016). For the preprocessing of the SCR in µS, the maximum and the mean values were calculated. The EMG preprocessing included a 28-Hz high-pass filter, a 50-Hz notch filter, a low-pass filter (15.92 Hz), and a 50-ms moving average filter.

For further analysis of the physiological correlates of intrusive memories, the physiological measures were exported for a period from -2 to 4.5 seconds around each key press. This period was chosen to account for the reaction latency from intrusive memory retrieval until button press (Schlagman & Kvavilashvili, 2008) and the delay in skin conductance response (SCR) from event onset until SCR peak (Gramann & Schandry, 2009; Wegerer et al., 2013).

Following preprocessing, reactivity values for both sessions were calculated for the SCR and EMG measures (Strohm et al., 2021). The difference between the reactivity during each intrusion period (from -2 to 4.5 seconds around the key press) and a 2-second intrusion-based baseline (-4 to -2 seconds before the key press) was used. The baseline was chosen based on studies using conditioned stimuli to adequately capture the phasic response to an intrusion relative to a pre-stimulus baseline (see Wegerer et al., 2013). The phasic skin conductance response (SCR) was calculated by subtracting the average skin conductance level (SCL) during the 2-second pre-intrusion baseline phase from the maximum SCR during the 6.5-second intrusion period. The reactivity measures were averaged over the 5-minute intrusion period.

For the EMG reactivity (in μV), the mean of the 2-second intrusion-based baseline was subtracted from the mean of each 6.5-second intrusion time window. These reactivity measures were then averaged over the 5-minute phase.

Voluntary Memory

Free Recall Task – Memory Disorganization and Incoherence. To assess the quality of autobiographical event memory, participants were asked to provide a detailed verbal report of an aversive life event. In line with previous studies (e.g., Halligan et al., 2003; Jelinek et al., 2009), they were instructed to recall the event as vividly, clearly, and accurately as possible, describing it in chronological order with as much detail as possible. The experimenter did not interrupt participants during the recall task. Following the methods of Foa et al. (1995) and Halligan et al. (2003), the free recall task was audio recorded and transcribed verbatim. The transcripts were coded for memory organization and coherence by independent raters who were blind to the randomization status and the time of measurement and did not conduct any of the interviews. The transcribed narrative was divided into chunks, containing only "one thought, action or speech utterance".

Memory Disorganization. To assess memory organization, which reflects the structural organization of the narrative, each chunk was assigned to one of six categories: Repetition, Disorganized Thought (i.e., clear expressions of uncertainty with regard to memory, confusion or disjointed thinking), Organized Thought (i.e., clauses involving attempts to understand what is happening such as planning, reasoning, decision-making, realising), Unfinished Thought (i.e. chunks involving a sentence attempted but not completed), Detail (i.e., all utterances that do not correspond to any of the above categories and contain descriptions of the time, place or events taking place) and Not Coded. In line with earlier research (e.g., Halligan et al., 2003; Jelinek et al., 2010), (a) repetitions, (b) disorganized thoughts and (c) organized thoughts were used as indices of memory organization. After z-transformation of each score, a total disorganization score was calculated as z (a) + z (b) – z(c). Following Jelinek et al. (2010), the category "unfinished thoughts" was reported separately. We additionally analyzed the distinct components of the total disorganization score separately (i.e., repetitions, disorganized thoughts, organized thoughts) (Crespo & Fernandez-Lansac, 2016; Jelinek et al., 2010). In addition, the rater provided a global rating of disorganization, from 0 (not at all disorganized) to 10 (extremely disorganized) after carefully reading each narrative (see Halligan et al., 2003). Interrater reliability (intraclass correlation [*ICC*]) was generally good (disorganized thoughts = .85, organized thoughts = .96, unfinished thoughts = . 94, repetitions = .87, total disorganization score = .99).

Memory Coherence. In addition to memory disorganization, we assessed memory coherence which reflects the conceptual organization of the narrative (e.g., Bedard-Gilligan et al., 2017). Following the Narrative Coherence Coding Scheme (Reese et al., 2011), three indices for memory coherence were assessed and each rated on a scale from 0 – 4: 1) context,

2) chronology and 3) theme. Interrater reliability (squared weighted kappa) was generally fair to moderate for the dimensions context = .35 and theme = .54; inter-rater agreement for the chronology dimension was poor (< .2), which is why we dropped this dimension from later analyses (Fleiss et al., 2003).

Free Recall Task - Memory Consistency. Empirical findings suggest that the effects of trauma-focused interventions on the (dis)organization and coherence of voluntary memory recall may not necessarily be linked to changes in memory content (Bedard-Gilligan et al., 2017a; Foa et al., 1995; Jaeger et al., 2014). Therefore, we additionally exploratively assessed the effects of ImRs, EMDR, and IE compared to NIC on memory consistency (e.g., Smeets et al., 2004).

To assess the consistency of memory recall, the details reported in Session 1 and Session 2 were compared. The transcripts were segmented into informational details (adapted from Levine et al., 2002, see Ganslmeier et al., 2022; Ganslmeier et al., 2023) and categorized as either internal details (specific to the reported event: event, place, time, perceptual, emotion/thought) or external details (not specific to the reported event: semantic knowledge, metacognition, repetition, other details). Only internal details were rated as consistent or inconsistent according to the following criteria (e.g., Smeets et al., 2004): Details were rated as inconsistent when they were reported in Session 1 but not in Session 2 (omissions), when they were reported in Session 2 but not in Session 1 (additions), and when the details reported in Session 1 were different from those in Session 2 (contradictions). Repeated additions, omissions, or contradictions involving the same piece of information were counted only once and not rated multiple times. Interrater reliability (ICC) was generally satisfactory (additions = . 98, contradictions = . 59, ommissions = .98).

Trauma Memory Questionnaire – Self-reported Memory Disorganization. There may be a dissociation between objectively coded and subjectively experienced memory quality. For instance, gaps in narratives might be mistakenly attributed to memory disorganization when they actually reflect avoidance behavior (cf. Halligan et al., 2003). To capture this, we used the Disorganization Subscale of the Trauma Memory Questionnaire (Halligan et al., 2003) to exploratively assess self-reported memory quality. This subscale consists of five items that assess deficits in intentional recall, such as *"I have trouble remembering the order in which things happened during the event."* on a scale ranging from 0 (= not at all) to 4 (= very strongly).

Interventions

Participants were randomly assigned to one of the three intervention conditions (EMDR, ImRs, or IE) or to a no intervention control group (NIC). Participants in the intervention groups received one single intervention session. All interventions were provided by post-graduate clinical trainees (CBT) with multiple years of clinical training. All investigators received supervision provided by LW and met for supervision sessions on a regular basis. The exact wording of the instructions for all interventions can be found on the OSF (https://osf.io/tnkr7/, Materials).

Memory reactivation task

To sufficiently reactivate the emotions before the intervention, all interventions (ImRs, IE, EMDR) were preceded by a brief imagery exercise (see Kunze et al., 2017). Participants were instructed to close their eyes and imagine the beginning of the scene until they reached the most distressing part of their memory ("hotspot"). In order for the experimenter to be able to follow the participants' mental images, they were asked to describe the images out loud with as much detail as possible. They rated the subjective distress associated with the memory before and after this short reactivation (see Table 11 for statistics). In addition, memory vividness was assessed post-reactivation. Following this, they proceeded with the respective intervention. Each intervention continued until the participants' subjective distress was reduced to 1 or lower on a scale from 0 to 10, with a minimum duration of 35 minutes and a maximum of 60 minutes.

Imagery Rescripting

The ImRs protocol was adapted from Arntz and Weertman (1999) (see Kunze et al., 2017). The intervention started with a short explanation of the rationale and the memory reactivation as described above. Once the hotspot of their memory was reached, participants were asked to change the scenario in their imagination into a more benign and less distressing one and to imagine the new script as vividly and detailed as possible. For example, participants whose distressing event was an interpersonal conflict imagined how they confronted the conflict partner, stood up for themselves and expressed their anger. During the imagination, the investigator asked in-depth questions, e.g., about thoughts, sensory, emotional and bodily sensations. The ImRs session concluded once participants indicated they were completely satisfied with the outcome, or when the maximum duration of 60 minutes was reached.

EMDR

We used an adapted version of the EMDR protocol from the IREM study (Boterhoven De Haan et al., 2020) which was based on the original protocol outlined by Shapiro (2001). The protocol included six phases: 1) a brief explanation of the rationale, 2) preparation, 3) target assessment, 4) desensitization and reprocessing, 5) introduction and installation of positive cognition, and 6) body check. The positive cognition was introduced only after subjective distress was reduced to 2 or lower on a scale from 0 to 10 during the desensitization phase. Eye movements were induced using the EMDR kit, version 2.0 (see https://www.emdrkit.com), which displayed a white dot moving left to right (speed: ca. 1 Hz in the desensitization phase, ca. 0,3 Hz during installation of positive cognition) on a 70 cm light bar during multiple episodes of 24 seconds each. Investigators monitored the participants' eye movements to ensure compliance with the instructions.

Imaginal Exposure

Based on Kunze et al. (2017), the IE intervention protocol used in the present study was adapted from Foa and Rothbaum (1998). It began with a brief explanation of the rationale, followed by memory reactivation and imaginal exposure to the autobiographical memory. Participants were asked to imagine the entire scene as vividly as possible. Similar to the ImRs protocol, they were encouraged to focus on and report about any sensory, emotional or bodily perceptions and thoughts that occurred throughout the imagination.

No-intervention control (NIC)

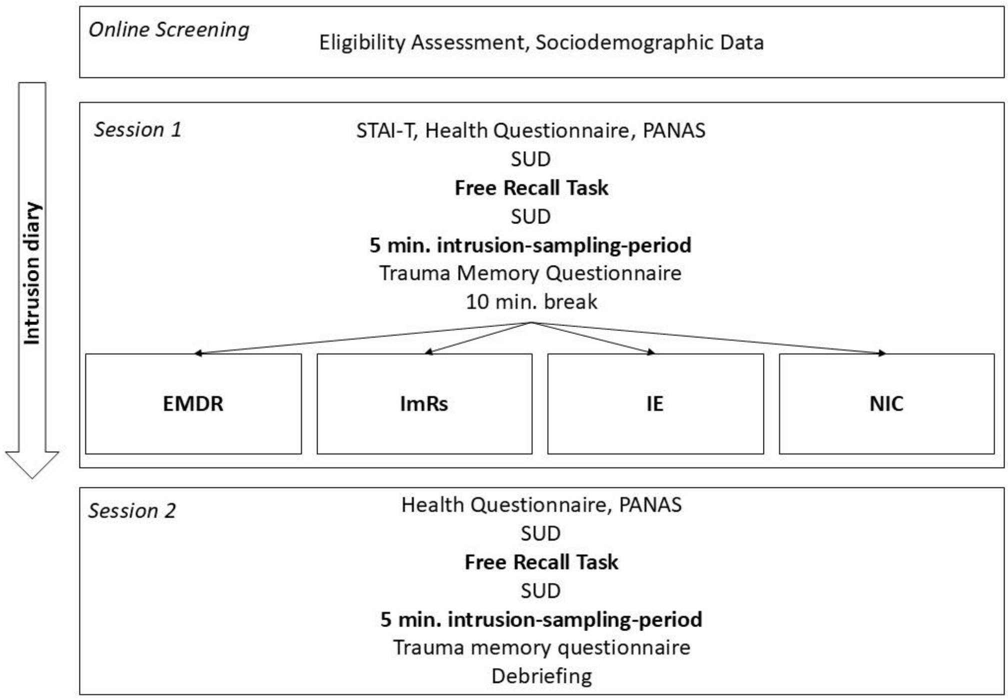
Participants in the NIC group did not receive any intervention.

Procedure

See Figure 5 for a schematic overview of the study procedure.

Figure 5

Schematic Overview of the Study Procedure



Note. *PANAS* Positive and Negative Affect Schedule, *SUD* Subjective Units of Distress *EMDR* Eye Movement Desensitization and Reprocessing, *ImRs* Imagery Rescripting, *IE* Imaginal Exposure, *NIC* No Intervention Control.

Online Screening

Participants were given an overview of the study procedure and the requirements for study participation via an online form. They were informed that they would be asked to deal with a stressful autobiographical memory as part of their participation in the study and that they could withdraw from study participation at any time. After giving informed consent, participants were directed to a brief online screening where basic inclusion criteria were assessed. Those who met the inclusion criteria provided sociodemographic data (age, gender, education, nationality) and were invited to the first experimental session. Participants who did not meet the inclusion criteria were not invited to attend future appointments.

Session 1

At the beginning of the first session, participants received detailed information about the study procedures and completed a standardized interview and a questionnaire to assess exclusion criteria related to alcohol and drug consumption, as well as their autobiographical memory. Eligible participants continued by completing a short health questionnaire, the PANAS, and the STAI-T. The session then proceeded with the attachment of electrodes for physiological measurements. Participants were instructed on and performed the free recall task. Subjective distress was assessed before and after the task. This was followed by a 5-minute lab-based intrusion sampling period and the completion of the trauma memory questionnaire. After electrode detachment and a 10-minute break, participants were randomly allocated to one of four groups, IE, EMDR, IR, or NIC, using a computer-generated allocation sequence. For participants in the IE, EMDR, and ImRs groups, the intervention phase followed. For those in the NIC group, the first day of testing concluded after the recall task.

Session 2

Participants returned to the laboratory one week later for the second session. The session began with the completion of the health questionnaire and the PANAS, followed by the attachment of electrodes for physiological measurements. Participants then performed the free recall task for the second time. Subjective distress was again assessed before and after the task. As in the first session, the free recall task was followed by a lab-based intrusion sampling period and the completion of the trauma memory questionnaire. Subsequently, the intrusion diary was reviewed with the participants, and they filled out the intrusion diary compliance questionnaire. The session concluded with a debriefing and compensation.

Statistical Analyses

All statistical analyses were conducted in R (R Development Core Team, 2023). For transparency, R Code for the analyses as well as the data set and corresponding codebook can be found on OSF (https://osf.io/tnkr7/, Analytic Code & Data).

Baseline Differences

To identify possible covariates, several univariate ANOVAs were conducted on QIDS-SR16, STAI-T, PANAS (session 1 and session 2), PCL-5 and sleep in order to assess differences between the four groups (ImRs, EMDR, IE, NIC).

Manipulation Checks

Emotional distress caused by the free recall task

To check how distressing the autobiographical event was experienced at the time of study participation, we assessed subjective distress induced by the free recall task in Session 1. A 2 (*time*: pre-recall vs. post-recall) x 4 (*intervention:* EMDR vs. ImRs vs. IE vs. NIC) mixed ANOVA was conducted for SUD-ratings as dependent variable, with time as within-subject factor and condition as between-subjects factors.

Memory Reactivation pre-intervention in Session 1

To assess whether the memory was sufficiently and equally reactivated before the interventions, a 2 (*time:* pre-reactivation vs. post-reactivation) x 4 (*intervention:* EMDR vs.

ImRs vs. IE vs. NIC) mixed ANOVA with time as within-subject factor and condition as between-subject factor was conducted for SUD ratings as dependent variable. In addition, a univariate ANOVA with the between-subjects factor intervention group (EMDR vs. ImRs vs. IE vs. NIC) was conducted to assess group differences in memory vividness ratings at post-memory reactivation.

Analyses of primary hypotheses

Given that count data have their own value do main (positive integer), we deviated from our pre-registered plan to use a mixed ANOVA to examine differences in intrusion reduction between the three interventions and NIC. For the same reason, we deviated from using mixed MANOVAs to evaluate group differences in changes across different dimensions of memory quality (number of repetitions, organized thoughts, disorganized thoughts) and memory consistency (number of omissions, additions, contradictions, consistent details) from pre- to post-intervention. To address the problem of non-normality and overdispersion, we instead considered several different models, including poisson, zero-inflated poisson, quasipoisson, and negative binomial regressions. We selected the most appropriate model for each analysis based on a systematic evaluation of model fit and leave-one-out cross-validation (Vehtari et al., 2017).

Hypothesis 1: Group differences in intrusion number and psychophysiological responding

Intrusion diary data. A two-level poisson regression model with random intercepts was estimated to predict intrusion number. The models included time (level 1, pre- vs. post-intervention), intervention group (level 2, NIC, EMDR, ImRs, IE), and their interaction as predictors. NIC and pre-intervention were used as reference categories for the predictors intervention and time. Group differences on the number of participants who did not report any intrusive memories at baseline (pre-intervention) were explored using chi-square tests (Siegesleitner et al., 2019).

Lab-based intrusions. Group differences in the number of intrusions experienced in the laboratory were assessed with a 2 (*time:* session 1 vs. session 2) x 4 (*intervention:* EMDR vs. ImRs vs. IE vs. NIC) mixed ANOVA. Group differences in the psychophysiological reactivity to intrusions experienced in the laboratory were assessed with two 2 (*time:* session 1 vs. session 2) x 4 (*intervention:* EMDR vs. ImRs vs. IE vs. NIC) mixed ANOVAs for SCR and EMG as dependent variables. Additionally, group differences on the number of participants who did not report any intrusive memories in session 1 or session 2 were explored using chi-square tests (Siegesleitner et al., 2019).

Hypothesis 2 & Hypothesis 3: group differences in voluntary memory quality

We estimated several poisson regression models with random intercept to predict group differences in the change of memory disorganization (i.e., number of organized thoughts, disorganized thoughts, repetitions and unfinished thoughts). All models included intervention group (NIC, EMDR, ImRs, IE) and time (pre- and post intervention) as predictors. NIC and pre-intervention were used as reference categories for the predictors intervention and measurement period. In addition, we added an offset term in order to control for the relationship between the number of (dis-)organized thoughts, unfinished thoughts and repetitions and the total number of chunks. Due to zero-inflation in the data, zero-inflated poisson regressions were used to model the number of organized thoughts and unfinished thoughts in the free recall task.

To assess group differences in the change of the global disorganization score and the total disorganization score, two 2 (*time:* pre- vs. post-intervention) x 4 (*intervention:* EMDR, ImRs, IE, NIC) mixed ANOVAs were conducted.

Exploratory analyses

Voluntary memory consistency

Negative binomial regression analyses were conducted to predict the number of omissions, contradictions, and additions. Each model included intervention group (NIC, EMDR, ImRs, IE) and time (pre- and post-intervention) as predictors. NIC and pre-intervention were used as reference categories for the intervention and time predictor variables. Additionally, we controlled for the total number of details reported at baseline by including it as a predictor.

Intrusion distress and intrusion load.

In addition to the total number of intrusions, we exploratively assessed the intervention effects on intrusion distress and intrusion load. Two two-level negative binomial regression models with random intercepts were estimated to predict intrusion distress and intrusion load. The models included time (level 1, pre- vs. post-intervention), intervention group (level 2, NIC, EMDR, ImRs, IE), and their interaction as predictors. NIC and pre-intervention were used as reference categories for the intervention and time predictor variables.

For effect sizes, 95% confidence intervals were computed in all analyses. Bonferroni corrections were conducted for post-hoc tests.

Results

Baseline and control variable differences between conditions

As illustrated in Table 11, there were no significant differences between the four groups in terms of sociodemographic or control variables. However, the duration of the intervention differed significantly between groups, F (2, 132)= 11.05, p = < .001, $\eta_p^2 = 0.14$, 95 % *CI* [0.04; 0.25]. Post hoc Tukey's HSD test revealed that ImRs was significantly shorter than EMDR and IE, both $p_{adj.} < .001$. IE and EMDR did not differ significantly from each other in intervention length, $p_{adj} = 0.18$. In addition, the groups differed in the length of memory reactivation, F (2, 112) = 3.57, p = .03, $\eta_p^2 = 0.06$, 95 % *CI* [0.00; 0.15]. Post-hoc Tukey's HSD test revealed that memory reactivation was significantly shorter in EMDR than in ImRs, *p adj*. = .03. IE and EMDR as well as ImRs and IE did not differ significantly from each other in length of memory reactivation, both *p adj* > .08.

Table 11

Sociodemographic and Control Variables

Variables	Condition				Statistics	*p*
	EMDR (*n* = 45)	ImRs (*n* = 46)	IE (*n* = 48)	NIC (*n* = 43)		
Sociodemographic Variables						
	M(SD)	*M(SD)*	*M(SD)*	*M(SD)*		
Age	22.82 (3.44)	23.20 (3.28)	23.42 (3.87)	23.52 (3.84)	F(3,178) = 0.32	.81
Number of years of education	14.38 (3.27)	15.09 (3.00)	15.69 (3.74)	15.60 (3.40)	F(3,178) = 1.45	.23
Gender (female)	86,67 %	80,43 %	83,33 %	81,40 %	$\chi^2(6) = 3.89$	.69
German (yes)	77,78 %	82,61 %	75,00 %	88,37 %	$\chi^2(3) = 2.99$	.39
Student (yes)	80,00 %	84,78 %	89,58 %	81,40 %	$\chi^2(3) = 1.89$	.60
Control Variables	*M(SD)*	*M(SD)*	*M(SD)*	*M(SD)*		
Sleep before Session 1	7.02 (1.14)	7.02 (1.14)	6.96 (1.53)	7.12 (1.53)	F(3,178) = 0.11	.96
Sleep before Session 2	6.84 (1.26)	7.07 (1.24)	7.00 (1.10)	7.36 (1.50)	F(3,176) = 1.22	.30
QIDS-SR-16	9.33 (3.77)	9.20 (3.30)	9.15 (3.22)	9.26 (3.88)	F(3,178) = 0.02	.99
PCL-5	32.04 (12.48)	30.54 (11.48)	31.88 (11.49)	34.35 (12.51)	F(3, 178) = 0.77	.51
STAI-T	45.96 (9.91)	46.52 (10.43)	44.81 (9.90)	47.12 (11.41)	F(3,178) = 0.41	.75
PANAS: Negative affect session 1	18.02 (5.46)	16.80 (5.00)	18.23 (5.27)	18.28 (6.28)	F(3,178) = .73	.54
PANAS: Positive affect session 1	26.38 (5.25)	26.37 (6.90)	28.56 (6.42)	28.21 (6.41)	F(3,178) = 62.95	.19
Negative affect session 2	14.60 (4.56)	14.13 (4.63)	14.98 (5.44)	14.47 (4.92)	F(3,178) = 0.24	.87
PANAS:Positive affect session 2	26.96 (6.53)	26.89 (7.26)	27.50 (8.18)	29.07 (7.65)	F(3,178) = 0.81	.49
Compliance Intrusion Diary	22.91 (25.97)	25.39 (28.12)	21.17 (23.00)	21.56 (22.51)	F(3,174) = 0.26	.85
Duration memory reactivation (min.)	6.73 (2.56)	8.39 (2.66)	8.15 (2.42)	-	F(2,112) = 3.57	.03
Duration intervention (min.)	49.71 (11.17)	43.62 (10.15)	53.57 (9.52)	-	(2, 132) = 11.05	< .001

Note. *ImRs* Imagery Rescripting, *EMDR* Eye Movement Desensitization and Reprocessing, *IE* Imaginal Exposure, NIC no-intervention control group, *QIDS-SR-16* Quick Inventory of Depressive Symptomatology, *PCL-5* PTSD Checklist for DSM-5, *STAI-T* trait form of the State-Trait-Anxiety-Inventory, *STAI-S* state form of the State-Trait-Anxiety-Inventory, *PANAS* Positive and Negative Affect Schedule, *M* mean, *SD* standard deviation. Data on the length of memory reactivation was missing for 21 participants in the EMDR group, as this measure was introduced later in this group during the data collection process. Additionally, data on memory reactivation length was unavailable for three participants in the IE group and one participant in the ImRs group.

Manipulation checks

The results of the manipulation checks are briefly summarized here; detailed descriptive statistics and results can be found in the supplementary materials on OSF (https://osf.io/tnkr7/). The free recall task conducted during session 1 significantly increased subjective distress across all groups. The memory reactivation task preceding the interventions led to a significant increase in subjective distress ratings in IE and ImRs, but not in EMDR. No group differences in memory vividness were found post-memory reactivation.

Main analyses: Intervention effects on involuntary and voluntary memory retrieval

Involuntary Memory

Intrusive memories assessed with the app-based intrusion diary

For the analyses of the intrusion diary data, we conducted two separate sets of analyses, one excluding participants with insufficient intrusion diary compliance (subjectively rated inconsistency > 5 on a scale of 0-10) and one including these participants. As the results did not differ, we will only report results for the full sample (data and code for both analyses are available on the OSF: https://osf.io/tnkr7/).

Table 12

Descriptive Statistics of Main Outcome Variables for Involuntary Memory

Variables	Condition			
	EMDR (*n* = 44)	ImRs (*n* = 45)	IE (*n* = 48)	NIC (*n* = 42)
Intrusion diary	*n* (%)	*n* (%)	*n* (%)	*n* (%)
Participants who reported no intrusion pre-intervention	2 (4.55)	1 (2.22)	2 (4.17)	4 (9.52)
Participants who reported no post-intervention	16 (36.36)	18 (40.00)	15 (31.25)	18 (42.86)
	M(SD)	*M(SD)*	*M(SD)*	*M(SD)*
Mean Number of intrusions pre-intervention	0.90 (1.28)	0.65 (1.14)	0.87(1.35)	0.61(0.93)
Mean Number of intrusions post-intervention	0.31 (0.68)	0.17 (0.42)	0.41 (0.79)	0.25 (0.60)
Number of intrusions day 1	1.80 (1.32)	1.58 (1.99)	1.69 (2.43)	1.60 (1.55)
Number of intrusions day 2	0.98 (1.58)	0.51 (0.87)	0.73 (0.92)	0.67 (0.72)
Number of intrusions day 3	0.96 (1.18)	0.49 (0.84)	0.88 (1.02)	0.48 (0.71)
Number of intrusions day 4	0.77 (1.12)	0.33 (0.56)	0.67 (0.88)	0.43 (0.63)
Number of intrusions day 5	0.71 (1.49)	0.42 (0.58)	0.56 (0.82)	0.50 (0.67)
Number of intrusions day 6	0.57 (0.95)	0.53 (0.94)	0.67 (1.04)	0.38 (0.62)
Number of intrusions day 7	0.55 (0.79)	0.69 (1.06)	0.90 (1.31)	0.21 (0.52)
Number of intrusions day 8	0.55 (0.79)	0.31 (0.60)	0.52 (0.83)	0.50 (0.92)
Number of intrusions day 9	0.27 (0.54)	0.20 (0.41)	0.63 (1.14)	0.26 (0.67)
Number of intrusions day 10	0.30 (0.73)	0.18 (0.39)	0.33 (0.56)	0.14 (0.42)
Number of intrusions day 11	0.09 (0.29)	0.22 (0.47)	0.38 (0.76)	0.29 (0.60)
Number of intrusions day 12	0.36 (0.65)	0.07 (0.25)	0.31 (0.69)	0.14 (0.35)
Number of intrusions day 13	0.14 (0.41)	0.09 (0.29)	0.29 (0.65)	0.19 (0.51)
Number of intrusions day 14	0.46 (0.98)	0.13 (0.41)	0.40 (0.77)	0.21 (0.52)
Intrusions assessed in the lab				
Number of intrusions in Session 1	3.12 (2.13)	2.80 (2.65)	3.64 (2.55)	3.71 (2.95)
Number of intrusions in Session 2	2.86 (2.38)	1.57 (1.64)	2.49 (2.11)	3.15 (2.59)
EMG in Session 1	-0.04 (0.54)	0.01 (0.66)	-0.07 (0.50)	0.15 (0.60)
EMG in Session 2	0.13 (0.97)	0.14 (0.53)	0.13 (0.76)	0.00 (0.33)
SCR in Session 1	0.11 (0.20)	0.10 (0.18)	0.06 (0.12)	0.06 (0.09)
SCR in Session 2	0.05 (0.10)	0.17 (0.41)	0.08 (0.16)	0.07 (0.22)

Note. ImRs Imagery Rescripting, *EMDR* Eye Movement Desensitization and Reprocessing, *IE* Imaginal Exposure, *NIC* no-intervention control group, *EMG* Electromyography activity of the corrugator supercilii, *SCR* skin conductance response, *M* mean, *SD* standard deviation.

Group differences in the reduction of intrusion frequency from pre- to post- intervention. Descriptive statistics for the number of intrusive memories assessed with the intrusion diary app are displayed in Table 12. Details on coefficient estimates, confidence intervals, and test statistics can be found in Table 13. There was a significant effect of time on the number of intrusions with a significant reduction of intrusions over time. There was no main effect of intervention group on intrusion number. Against our expectations, only participants who received ImRs showed a significantly greater reduction of intrusions from pre- to post-intervention compared to NIC as indicated by a significant interaction of intervention x time. No significant differences in intrusion reduction were found between EMDR and NIC, nor between IE and NIC.

Table 13

Multilevel Poisson Regression Model Predicting the Reduction in Intrusion Number from Pre- to Post-Intervention with the Predictors time (pre-post-intervention), Intervention (NIC, EMDR, ImRs, IE) and their interaction

Predictor	Estimates (SE)	95% CI	z	p
(Intercept)	-0.76 (0.15)	[-1.05; -0.47]	-5.22	**< .001**
NIC vs. EMDR	0.35 (0.20)	[-0.04; 0.74]	1.77	.076
NIC vs. ImRs	0.08 (0.20)	[-0.32; 0.47]	0.38	.706
NIC vs. IE	0.31 (0.19)	[-0.07; 0.69]	1.57	.115
Post-Intervention_true	-0.90 (0.14)	[-1.17; -0.62]	-6.46	**< .001**
EMDR:Post-Intervention_true	-0.18 (0.18)	[-0.54; 0.18]	-0.97	.333
ImRs:Post-Intervention_true	-0.44 (0.21)	[-0.84; -0.03]	-2.12	**.034**
IE:Post-Intervention_true	0.14 (0.17)	[-0.20; 0.48]	0.81	.419

Note. ImRs Imagery Rescripting, *EMDR* Eye Movement Desensitization and Reprocessing, *IE* Imaginal Exposure, *NIC* no-intervention control group.

Table 14

Descriptive Statistics of Exploratory Analyses of Group Differences in the Reduction of Intrusion Distress and Intrusion Load from Pre- to Post-Intervention

Variables	Condition			
	EMDR (*n* = 44)	ImRs (*n* = 45)	IE (*n* = 48)	NIC (*n* = 42)
	M(SD)	*M(SD)*	*M(SD)*	*M(SD)*
Intrusion distress pre-intervention	55.71 (22.44)	58.40 (21.55)	54.35 (24.75)	58.84 (22.07)
Intrusion distress post-intervention	54.16 (22.23)	51.65 (22.31)	46.58 (24.47)	60.82 (20.64)
Intrusion load pre-intervention	150.79 (115.44)	162.24 (197.56)	152.89 (165.86)	126.33 (110.12)
Intrusion load post-intervention	100.63 (74.10)	60.94 (32.76)	85.92 (62.87)	101.53 (52.70)
Intrusion distress day 1	50.53 (24.10)	59.99 (23.52)	52.47 (22.48)	58.73 (23.12)
Intrusion distress day 2	62.26 (19.99)	48.96 (22.38)	57.74 (22.53)	52.43 (19.07)
Intrusion distress day 3	58.95 (23.22)	56.77 (18.41)	56.60 (21.67)	54.30 (25.01)
Intrusion distress day 4	56.24 (21.42)	57.80 (19.25)	47.00 (25.95)	68.11 (19.19)
Intrusion distress day 5	57.10 (20.83)	59.00 (22.05)	53.96 (28.39)	60.33 (21.89)
Intrusion distress day 6	51.92 (20.62)	62.92 (20.61)	60.91 (27.33)	62.81 (23.45)
Intrusion distress day 7	56.75 (22.97)	59.39 (19.48)	53.77 (27.72)	60.67 (16.58)
Intrusion distress day 8	54.75 (20.50)	56.57 (22.40)	57.68 (21.79)	55.10 (18.52)
Intrusion distress day 9	52.50 (26.89)	42.78 (16.12)	40.83 (24.74)	56.73 (16.76)
Intrusion distress day 10	53.39 (21.74)	56.25 (20.54)	39.81 (24.67)	51.00 (27.79)
Intrusion distress day 11	66.50 (26.80)	46.00 (21.41)	50.72 (21.81)	66.08 (26.43)
Intrusion distress day 12	45.75 (21.30)	68.33 (14.30)	34.40 (23.24)	54.83 (16.46)
Intrusion distress day 13	51.83 (28.99)	46.75 (17.80)	40.43 (22.15)	73.00 (14.18)
Intrusion distress day 14	59.90 (19.92)	51.67 (37.07)	56.95 (24.94)	71.89 (17.35)
Intrusion load day 1	138.92 (85.00)	266.56 (294.39)	267.16 (259.93)	193.91 (144.15)
Intrusion load day 2	212.44 (148.18)	101.39 (79.99)	110.31 (77.94)	79.04 (45.78)
Intrusion load day 3	143.45 (84.68)	105.68 (92.39)	115.79 (74.57)	86.05 (48.78)
Intrusion load day 4	127.32 (74.13)	76.60 (44.12)	74.00 (44.65)	96.00 (73.33)
Intrusion load day 5	217.26 (196.00)	73.84 (41.74)	77.89 (49.18)	87.14 (49.56)
Intrusion load day 6	101.72 (41.24)	127.29 (74.20)	136.59 (88.12)	86.31 (55.20)
Intrusion load day 7	90.71 (50.17)	131.29 (69.31)	126.49 (74.24)	83.11 (28.73)
Intrusion load day 8	101.42 (56.66)	82.50 (45.67)	107.64 (77.66)	113.14 (56.78)
Intrusion load day 9	72.33 (50.62)	42.78 (16.12)	84.80 (47.28)	109.55 (50.19)
Intrusion load day 10	127.23 (113.64)	56.25 (20.54)	43.88 (24.80)	67.33 (34.02)
Intrusion load day 11	66.50 (26.80)	55.70 (29.09)	92.22 (55.21)	107.08 (67.55)
Intrusion load day 12	66.81 (37.08)	68.33 (14.30)	66.40 (57.33)	54.83 (16.46)
Intrusion load day 13	67.67 (35.67)	46.75 (17.80)	70.57 (50.83)	108.50 (40.02)
Intrusion load day 14	143.15 (87.54)	58.67 (31.09)	115.26 (82.06)	105.00 (46.47)

Note. *ImRs* Imagery Rescripting, *EMDR* Eye Movement Desensitization and Reprocessing, *IE* Imaginal Exposure, *NIC* no-intervention control group.

Group differences in the reduction of intrusion distress from pre- to post- intervention. Descriptive statistics on intrusion distress can be found in Table 14. Details on coefficient estimates, confidence intervals, and test statistics are displayed in Table 15. We found no significant effect of time or intervention on intrusion distress. Significant time x intervention effects indicated that participants who received ImRs and IE exhibited a significantly greater reduction in intrusion distress from pre- to post-intervention compared to the NIC group. The EMDR group did not show a significantly greater reduction in intrusion distress compared to NIC.

Table 15

Multilevel Negative Binomial Regression Model Predicting Intrusion Distress with the Predictors time (pre- vs. post- intervention), Intervention (NIC, EMDR, ImRs, IE), and their interaction

Predictor	Estimates (SE)	95% CI	z	p
(Intercept)	4.00 (0.06)	[3.89; 4.11]	70.22	**< .001**
NIC vs. EMDR	-0.03 (0.08)	[-0.18; 0.12]	-0.39	0.700
NIC vs. ImRs	0.04 (0.08)	[-0.11; 0.19]	0.53	0.696
NIC vs. IE	-0.03 (0.08)	[-0.18; 0.12]	-0.37	0.713
Post-Intervention_true	0.09 (0.06)	[-0.02; 0.20]	1.55	0.121
EMDR:Post-Intervention_true	-0.14 (0.08)	[-0.29; 0.01]	-1.86	0.063
ImRs: Post-Intervention_true	-0.19 (0.09)	[-0.36; -0.03]	-2.27	**0.023**
IE: Post-Intervention_true	-0.20 (0.07)	[-0.34; -0.06]	-2.76	**0.006**

Note. ImRs Imagery Rescripting, *EMDR* Eye Movement Desensitization and Reprocessing, *IE* Imaginal Exposure, *NIC* No-intervention control group. NIC and Pre-intervention were reference categories for intervention group and measurement period, respectively.

Table 16

Multilevel Negative Binomial Model Regression Model Predicting the Intrusion Load with the Predictors Time (pre- vs. post- intervention), Intervention (NIC, EMDR, ImRs, IE), and their Interaction

Predictor	Estimates (SE)	95% CI	z	p
(Intercept)	4.47 (0.10)	[4.27; 4.67]	43.99	**< .001**
NIC vs. EMDR	0.08 (0.14)	[-0.19; 0.35]	0.61	.544
NIC vs. ImRs	0.07 (0.14)	[-0.20; 0.34]	0.50	.619
NIC vs. IE	0.08 (0.14)	[-0.19; 0.35]	0.60	.551
Post-Intervention_true	-0.01 (0.09)	[-0.18; 0.17]	-0.07	.948
EMDR: Post-Intervention_true	-0.37 (0.12)	[-0.60; -0.14]	-3.18	**.001**
ImRs:Post-Intervention_true	-0.59 (0.13)	[-0.85; -0.32]	-4.38	**< .001**
IE:Post-Intervention_true	-0.25 (0.11)	[-0.47; -0.03]	-2.24	**.025**

Note. *ImRs* Imagery Rescripting, *EMDR* Eye Movement Desensitization and Reprocessing, *IE* Imaginal Exposure, *NIC* No-intervention control group. NIC and Pre-intervention were reference categories for intervention group and measurement period, respectively.

Group differences in the reduction of intrusion load from pre- to post- intervention. Descriptive statistics on intrusion load can be found in Table 14. Details on coefficient estimates, confidence intervals, and test statistics are displayed in Table 16. There was no main effect of time or intervention group on intrusion load. All intervention groups showed a significantly greater reduction in intrusion load from pre- to post intervention than NIC, as indicated by significant time x intervention effects.

Number of participants who reported no intrusions pre- and post – intervention. The number of participants who recorded no intrusions during the week before the intervention did not differ significantly between groups, X^2 (3, N = 179) = 2.62, p = .45. Descriptive statistics can be found in Table 12. Neither did the number of participants who recorded no intrusions during the week after the intervention differ significantly between groups, X^2 (3, N = 179) = 1.46, p = .69.

Reduction of intrusive memories assessed in the laboratory

Descriptive statistics for intrusions assessed during the intrusion sampling period in the lab are displayed in Table 12.

Group differences in the number of intrusions assessed in the laboratory. There was a main effect of time, F (1, 174) = 21.80, $p < .001$, $\eta_p^2 = 0.11$, showing a significant reduction of intrusion number from Session 1 to Session 2. In addition, there was a significant main effect of intervention, F (3, 174) = 2.77, $p = 0.04$, $\eta_p^2 = 0.05$, with significantly less intrusions registered in ImRs than in NIC as indicated by pairwise comparisons, $p < .001$, $p_{adj} = .005$. There was no significant intervention x time interaction, F (3, 174) = 1.84, $p = 0.14$, $\eta_p^2 = 0.03$.

Group differences in psychophysiological reactivity to lab-based intrusions. No significant effects of intervention, time, or the time x intervention interaction were observed for EMG or SCR measures associated with intrusions during the intrusion sampling period in the laboratory (see the supplemental material on the OSF for detailed statistics: https://osf.io/tnkr7/, Supplements).

Voluntary Memory

Descriptive statistics for assessments of voluntary memory disorganization and coherence assessed with the free recall task are presented in Table 17.

Table 17

Descriptive Statistics of Main Outcome Variables for Voluntary Memory

Variables	Condition			
	EMDR (*n* = 42)	ImRs (*n* = 45)	IE (*n* = 47)	NIC (*n* = 42)
Memory organization	*M(SD)*	*M(SD)*	*M(SD)*	*M(SD)*
Chunks t1	99.56 (53.41)	105.58 (79.19)	113.81 (100.57)	87.90 (49.67)
Chunks t2	73.42 (38.48)	86.24 (61.49)	147.13 (115.04)	78.09 (50.11)
Disorganized thoughts t1	1.27 (1.80)	1.97 (2.80)	2.01 (2.35)	2.03 (2.46)
Disorganized thoughts t2	1.24 (1.78)	1.57 (2.10)	0.98 (1.23)	1.64 (2.59)
Unfinished thoughts t1	6.91 (5.24)	7.60 (9.31)	7.81 (11.32)	5.83 (5.89)
Unfinished thoughts t2	4.44 (4.05)	5.24 (5.11)	9.11 (10.32)	4.98 (4.75)
Repetitions t1	1.20 (1.44)	1.42 (2.20)	1.62 (2.01)	2.55 (3.93)
Repetitions t2	1.11 (1.42)	1.62 (2.24)	2.23 (2.37)	1.86 (2.99)
Organized thoughts t1	7.11 (4.34)	7.29 (7.09)	7.53 (8.30)	7.45 (5.13)
Organized thoughts t2	5.13 (3.26)	5.56 (5.56)	9.77 (9.10)	6.79 (5.40)
Total disorganization t1	-0.39 (1.09)	-0.20 (1.54)	0.17 (1.17)	0.44 (2.04)
Total disorganization t2	-0.21 (0.91)	0.12 (1.28)	-0.09 (1.31)	0.20 (2.05)
Subjective disorganization t1	0.97 (0.60)	0.99 (0.68)	1.24 (0.90)	1.13 (0.80)
Subjective disorganization t2	0.94 (0.54)	1.14 (0.71)	1.24 (0.74)	1.23 (0.67)
Global disorganization t1	3.56 (1.60)	3.13 (1.94)	3.72 (2.03)	3.07 (2.18)
Global disorganization t2	2.80 (1.49)	2.78 (1.36)	3.26 (1.74)	2.83 (2.00)
Memory coherence				
Chronology t1	2.67 (0.60)	2.69 (0.56)	2.85 (0.36)	2.62 (0.62)
Chronology t2	2.84 (0.42)	2.71 (0.51)	2.89 (0.31)	2.69 (0.60)
Context t1	2.60 (0.58)	2.38 (0.65)	2.58 (0.62)	2.48 (0.71)
Context t2	2.69 (0.609	2.47 (0.59)	2.57 (0.58)	2.33 (0.72)
Theme t1	2.44 (0.72)	2.24 (0.80)	2.60 (0.549	2.33 (0.85)
Theme t2	2.49 (0.669	2.22 (0.779	2.49 (0.69)	2.40 (0.70)
Memory Consistency				
Number of details at t1	78.16 (38.13)	74.89 (52.56)	84.04 (66.27)	68.00 (38.07)
Number of details at t2	63.18 (29.21)	66.96 (43.14)	110.00 (77.26)	62.67 (39.69)
Number of omissions	42.71 (27.84)	43.11 (39.81)	43.74 (36.93)	33.29 (20.27)
Number of additions	27.73 (18.57)	35.18 (28.31)	69.70 (50.57)	27.95 (23.73)
Number of contradictions	0.56 (0.76)	0.62 (0.91)	0.89 (1.18)	0.69 (0.87)
Consistency index	0.35 (0.11)	0.32 (0.13)	0.27 (0.09)	0.37 (0.11)

Note. *ImRs* Imagery Rescripting, *EMDR* Eye Movement Desensitization and Reprocessing, *IE* Imaginal Exposure, *NIC* no-intervention control group, *SUD* Subjective Stress, *SAM* Self-Assessment Manikins, *M* mean, *SD* standard deviation.

Voluntary Memory Disorganization – Chunk-Based-Assessment

Coefficient estimates, confidence intervals, and test statistics for group differences in the change in the number of disorganized thoughts, organized thoughts, repetitions and unfinished thoughts from pre- to post-intervention are displayed in Table 18.

Table 18

Results of Poisson Regressions Predicting the Number of Disorganized Thoughts and Repetitions and Zero-inflated Poisson Regressions Predicting the Number of Organized Thoughts and Unfinished Thoughts in the Free Recall Task with the Predictors Intervention (NIC, EMDR, ImRs, IE) and Time (pre- and post intervention)

Predictor	Estimates (SE)	95% CI	z	p
Organized thoughts				
(Intercept)	-2.49 (0.15)	[-2.79; -2.20]	-16.57	< **.001**
NIC vs. EMDR	-0.13 (0.21)	[-0.55; 0.28]	-0.62	.53
NIC vs. ImRs	-0.17 (0.21)	[-0.59; 0.24]	-0.81	.42
NIC vs. IE	-0.34 (0.21)	[-0.74; 0.06]	-1.67	.09
Time	-0.01 (0.08)	[-0.18; 0.15]	-0.18	.86
EMDR:Time	-0.03 (0.12)	[-0.26; 0.21]	-0.22	.83
IE:Time	0.04 (0.11)	[-0.17; 0.26]	0.39	.70
ImRs:Time	-0.08 (0.12)	[-0.31; 0.16]	-0.64	.52
Disorganized thoughts				
(Intercept)	- 4.26 (0.30)	[-4.85; -3.68]	- 14.18	< **.001**
NIC vs. EMDR	-0.61 (0.47)	[-1.52; 0.31]	-1.30	.19
NIC vs. ImRs	-0.26(0.43)	[-0.26; 1.32]	-0.59	.56
NIC vs. IE	0.53 (0.40)	[-1.11; 0.60]	1.32	.19
Time	-0.05 (0.16)	[-0.38; 0.27]	-0.34	.74
EMDR:Time	0.12 (0.27)	[-0.41; 0.65]	0.44	.66
IE:Time	-0.51 (0.22)	[-0.95; -0.08]	-2.32	**.02**
ImRs:Time	0.08 (0.24)	[-0.40; 0.56]	0.33	.74

Table 18 (continued)

Predictor	Estimates (SE)	95% CI	z	p
Repetitions				
(Intercept)	-3.78 (0.27)	[-4.31; -3.26]	-14.18	< **.001**
NIC vs. EMDR	-1.07 (0.43)	[-1.91; -0.24]	-2.52	**.01**
NIC vs. ImRs	-1.05 (0.41)	[-1.84; -0.25]	-2.58	< **.001**
NIC vs. IE	-0.81 (0.39)	[-1.56; -0.05]	-2.09	**.04**
Time	-0.19 (0.15)	[-0.48; 0.11]	-1.25	.21
EMDR:Time	0.41 (0.25)	[-0.07; 0.90]	1.66	.10
IE:Time	0.28 (0.21)	[-0.14; 0.70]	1.29	.20
ImRs:Time	0.47 (0.23)	[0.02; 0.92]	2.06	**.04**
Unfinished thoughts				
(Intercept)	-2.86 (0.18)	[-3.21; -2.52]	-16.11	< **.001**
NIC vs. EMDR	0.30 (0.24)	[-0.17; 0.77]	1.26	.21
NIC vs. ImRs	0.23 (0.24)	[-0.24; 0.70]	0.97	.33
NIC vs. IE	-0.08 (0.23)	[-0.54; 0.38]	-0.34	.73
Time	-0.03 (0.10)	[-0.22; 0.15]	-0.35	.73
EMDR:Time	-0.13 (0.13)	[-0.39; 0.13]	-0.97	.33
IE:Time	-0.00 (0.12)	[-0.24; 0.24]	-0.00	1.00
ImRs:Time	-0.15 (0.13)	[-0.40; 0.11]	-1.13	.26

Note. ImRs Imagery Rescripting, *EMDR* Eye Movement Desensitization and Reprocessing, *IE* Imaginal Exposure, *NIC* no-intervention control group.

Number of organized thoughts. There was no significant main effect of intervention group or time. Also, there was no significant intervention group x time interaction.

Number of disorganized thoughts. There was no significant main effect of intervention group or time. However, a significant group × time interaction was observed for IE compared to NIC. Specifically, the IE group demonstrated a significantly greater reduction in disorganized thoughts from pre- to post-intervention. EMDR and ImRs did not show significant differences from the NIC in the change in disorganized thoughts over time.

Number of repetitions. There was a significant main effect of intervention group, indicating that participants in EMDR, ImRs, and IE showed significantly fewer repetitions compared to NIC. There was no significant main effect of time. A significant group × time interaction emerged for ImRs compared to NIC. Specifically, ImRs showed a significantly greater increase in repetitions from pre- to post-intervention than NIC. Apart from that, there was no significant time x intervention interaction effect on the number of repetitions for IE or EMDR.

Number of unfinished thoughts. There were no significant main effects of intervention or time, nor did we observe a significant time x intervention interaction effect on the number of unfinished thoughts.

Total Disorganization score. For the total disorganization score, no main effect of time, $F(1, 175) = 0.00$, $p = 0.99$, $\eta_p^2 = 0.00$, 95% *CI* [0.00, 0.00] or intervention, $F(3, 175) = 1.66$, $p = 0.18$, $\eta_p^2 = 0.03$, 90% *CI* [0.00, 0.07] was observed. Neither did we find a significant interaction between intervention and time, $F(3, 175) = 2.46$, $p = .07$, $\eta_p^2 = 0.04$, 95% *CI* [0.00, 0.09].

Voluntary Memory Disorganization – Assessments Based on the Entire Narrative

Global disorganization score as perceived by the rater. For the global disorganization score, a main effect of time, $F(1, 175) = 18.45$, $p < .001$, $\eta_p^2 = 0.10$, 95% *CI* [0.00, 0.06] was found, indicating that the global disorganization decreased from pre to post intervention in all groups. No significant effect of intervention, $F(3, 175) = 1.06$, $p = 0.37$, $\eta_p^2 = 0.02$, 90% *CI* [0.00, 0.06] or interaction between intervention and time were observed, $F(3, 175) = 1.08$, $p = .36$, $\eta_p^2 = 0.02$, 95% *CI* [0.00, 0.06].

Subjective memory disorganization as perceived by the participant. For subjective memory disorganization, we found no main effect of time, F (1, 175) = 0.92, $p = 0.34$, $\eta_p^2 = 0.01$, 95 % *CI* [0;0.05], or intervention, F (3, 175) = 1.83, p = 0.14, η_p^2 = 0,03, 95 % *CI* [0;0.08]. Neither did we find a significant interaction between intervention and time, F (3; 175) = 1.18, $p = .32$; $\eta_p^2 = 0.02$, 95 % *CI* [0; 0.06].

Voluntary Memory Coherence

Coefficient estimates, confidence intervals, and test statistics for group differences in the change in contextual and thematic memory coherence are displayed in Table 19[2].

Context. EMDR and ImRs showed a marginally significantly greater increase in context ratings from pre- to post intervention as compared to NIC ($p = .050$). No differences were found between IE and NIC regarding the change of context ratings from pre- to post intervention.

Theme. None of the intervention groups did significantly differ from NIC in the change in theme ratings from pre- to post-intervention.

[2]Due to the low inter-rater reliability for the chronology dimension, we have not included the detailed results on this dimension in the main text, but provide them as supplementary materials on OSF (https://osf.io/tnkr7/, Supplements). No significant group differences were found for the chronology dimension.

Table 19

Results of linear mixed models predicting memory coherence (context, chronology and theme) by the Predictors Intervention (NIC, EMDR, ImRs, IE) and time (pre- and post intervention) and their interaction.

Predictor	Estimates (SE)	95% CI	t	p
Context				
(Intercept)	2.48 (0.10)	[2.29; 2.67]	25.46	**< .001**
NIC vs. EMDR	0.12 (0.14)	[-0.14; 0.39]	0.92	.36
NIC vs. ImRs	-0.10 (0.14)	[-0.36; 0.16]	-0.73	.47
NIC vs. IE	0.10 (0.13)	[-0.16; 0.36]	0.73	.46
Time	-0.14 (0.08)	[-0.31; 0.02]	-1.69	.09
EMDR:Time	0.23 (0.12)	[0.00; 0.46]	1.97	.05
IE:Time	0.14 (0.12)	[-0.08; 0.37]	1.23	. 22
ImRs:Time	0.23 (0.12)	[0.00; 0.46]	1.97	.05
Theme				
(Intercept)	2.33 (0.11)	[2.12; 2.55]	21.03	**< .001**
NIC vs. EMDR	0.11 (0.15)	[-0.19; 0.41]	0.72	.47
NIC vs. ImRs	-0.09 (0.15)	[-0.39; 0.21]	-0.58	.57
NIC vs. IE	0.26 (0.15)	[-0.03; 0.56]	1.72	.09
Time	0.07 (0.09)	[-0.10; 0.25]	0.79	.43
EMDR:Time	-0.03 (0.13)	[-0.27; 0.22]	-0.22	.83
IE:Time	-0.18 (0.12)	[-0.42; 0.06]	-1.43	.15
ImRs:Time	-0.09 (0.13)	[-0.34; 0.15]	-0.75	.46

Note. *ImRs* Imagery Rescripting, *EMDR* Eye Movement Desensitization and Reprocessing, *IE* Imaginal Exposure, *NIC* no-intervention control group.

Memory Consistency

Descriptive statistics for assessments of memory consistency indices assessed with the free recall task are presented in Table 18. Coefficient estimates, confidence intervals, and test statistics for memory consistency analyses are displayed in Table 20.

Table 20

Results of Negative Binomial Regressions Predicting the Number of Omissions, Contradictions and Additions in the Free Recall Task with the Predictors Intervention (NIC, EMDR, ImRs, IE) and time (pre- and post intervention) and an added Offset Term for Total Number of Reported Details in Session 1.

Predictor	Estimates (SE)	95% CI	Test statistic	p
Omissions				
(Intercept)	2.37 (0.06)	[2.27; 2.48]	42.79	**<.001**
NIC vs. EMDR	0.04 (0.06)	[-0.08; 0.15]	0.61	0.54
NIC vs. ImRs	0.05 (0.06)	[-0.07; 0.17]	0.83	0.41
NIC vs. IE	0.09 (0.06)	[-0.02; 0.21]	1.59	0.11
details_t1	0.02 (0.00)	[0.02; 0.03]	32.41	**<.001**
Additions				
(Intercept)	2.58 (0.11)	[2.35; 2.82]	23.81	**<.001**
NIC vs. EMDR	-0.04 (0.13)	[-0.29; 0.20]	-0.35	0.73
NIC vs. ImRs	0.17 (0.13)	[-0.08; 0.41]	1.32	0.19
NIC vs. IE	0.81 (0.12)	[0.56; 1.05]	6.51	**<.001**
details_t1	0.01 (0.00)	[0.01; 0.01]	10.80	**<.001**
Contradictions				
(Intercept)	-0.78 (0.23)	[-1.25; -0.32]	-3.31	**<.001**
NIC vs. EMDR	-0.26 (0.29)	[-0.85; 0.32]	-0.89	0.372
NIC vs. ImRs	-0.17 (0.29)	[-0.74; 0.40]	-0.58	0.561
NIC vs. IE	0.11 (0.27)	[-0.42; 0.65]	0.41	.679
details_t1	0.01 (0.00)	[0.00; 0.01]	3.56	**<.001**

Note. ImRs_Sensory Imagery Rescripting with sensory-perceptual focus, *ImRs_NotSensory* Imagery Rescripting without sensory-perceptual focus, *NIC* no-intervention control group.

Group differences in the number of omissions. Negative binomial regression was employed to predict the number of omissions. The analysis showed no significant differences between NIC and EMDR, ImRs, or IE. The total number of details reported at baseline was a significant positive predictor of number of omissions.

Group differences in the number of additions. The results of the negative binomial regression revealed that the IE group reported significantly more additions compared to the NIC group. No significant differences were observed between the NIC group and the EMDR or ImRs groups. The baseline number of details was a significant positive predictor of number of additions.

Group differences in the number of contradictions. The results of the negative binomial regression analysis showed no significant differences between the NIC and EMDR, ImRs, or IE. The total number of details reported at baseline was a significant positive predictor of number of contradictions.

Discussion

This study investigated the differential effects of three trauma-focused interventions, namely ImRs, EMDR and IE, on involuntary and voluntary memories of an aversive autobiographical event in healthy participants.

The main findings of the present study are partly consistent with our predictions regarding the distinct effects of these interventions on involuntary vs. voluntary memory recall.

Intervention effects on involuntary memory

We predicted that all three interventions would reduce involuntary memories compared to NIC. We based this prediction on prior research, demonstrating the efficacy of trauma-focused treatments in reducing intrusive memories (e.g., Cusack et al., 2015; Kip et al., 2023). Contrary to our expectations, ImRs was the only intervention associated with a significantly greater reduction in the number of intrusions from pre- to post-intervention compared to NIC, as assessed by the app-based intrusion diary. This result is somewhat surprising, given that both IE and EMDR are guideline-recommended interventions proven to be effective in reducing the core symptoms of PTSD, including intrusive memories (APA, 2017). One possible explanation for the lack of significant intrusion reduction in the EMDR and IE groups may be the overall low frequency of intrusions recorded during the week prior to the intervention. Although we attempted to minimize floor effects by including only participants who reported intrusive memories at eligibility assessment, the autobiographical memories investigated in this study may have been too mild to reliably detect significant intervention effects on the number of intrusions.

Our exploratory analyses of the diary data appear to support this assumption as all intervention groups were more effective than NIC in reducing intrusion load (i.e., the number of intrusions weighted by associated distress). Additionally, ImRs and IE were linked to a significantly greater reduction in intrusion distress compared to NIC. These findings are clinically relevant, given that intrusions perceived as distressing are particularly important in the context of PTSD (Michael et al., 2005; Steil & Ehlers, 2000; see also previous analogue studies which focused on the assessment of intrusion load instead of frequency for this reason, e.g., Rattel et al., 2024; Rattel, Miedl, et al., 2019).

Analyses of intrusions assessed in the laboratory showed a similar pattern, with ImRs and IE, but not EMDR, leading to a significantly greater reduction in the number of intrusions between sessions compared to NIC. However, we did not observe the expected group differences in psychophysiological responses to intrusions, possibly due to the relatively mild nature of the memories in terms of both arousal and valence. Furthermore, the high amount of missing data caused by excessive signal noise may have diminished the statistical power needed to identify group differences. To the best of our knowledge, this is the first study to examine psychophysiological correlates (i.e., skin conductance response and facial muscle activity) of intrusion retrieval in a laboratory setting. As the exact timing of involuntary memory retrieval and its physiological correlates remains largely unknown, our assessment windows may not have been optimal for capturing these responses. Future studies might consider using an intrusion provocation task to narrow the assessment window in order to be able to better capture psychophysiological responses to intrusions (e.g., James et al., 2015).

Intervention Effects on Voluntary Memory Disorganization

We anticipated distinct effects of the interventions on voluntary memory disorganization and coherence. Based on previous studies (Bedard-Gilligan et al., 2017; Cooper et al., 2017), we expected that IE would not significantly improve memory organization and coherence, while EMDR and ImRs, which more explicitly target memory quality, would lead to changes compared to NIC. Our results are partly consistent with these predictions.

As expected, IE was not associated with significant changes in global measures of memory (dis-)organization, including both the total disorganization score, which was calculated by aggregating the individual disorganization indices assessed at the chunk level, and the global disorganization score, which was based on an overall evaluation of the entire event narrative. Similarly, self-reported memory disorganization ratings did not differ significantly between the IE and NIC groups. Furthermore, no significant differences between IE and NIC were observed in any of the three dimensions of memory coherence (theme, context).

However, when examining the individual disorganization indices of the total disorganization score separately, we found that participants in the IE group showed a significant reduction in disorganized thoughts compared to NIC. Interestingly, other indices of disorganization, such as unfinished thoughts and repetitions, did not exhibit significant changes, consistent with previous research (Foa et al., 1995; Van Minnen et al., 2002). Moreover, the reduction in disorganized thoughts was not accompanied by an increase in organized thoughts, supporting previous findings that these measures are not necessarily linked (Foa et al., 1995; van Minnen et al., 2002).

Overall, these findings are consistent with prior research suggesting that while IE may reduce certain aspects of disorganization, it does not reliably enhance overall memory coherence or organization (Bedard-Gilligan et al., 2017; Cooper et al., 2017). The significant reduction in intrusion load and distress following IE, despite the lack of consistent changes in memory disorganization and coherence, further supports the notion that improvements in memory organization and coherence may not be critical for successful recovery (Bedard-Gilligan et al., 2017; Cooper et al., 2017; van Minnen et al., 2002).

Our findings regarding EMDR and ImRs were only partly consistent with our predictions. As anticipated, both interventions were associated with some qualitative improvements in voluntary memory. Specifically, EMDR and ImRs led to significant increases in the "context" dimension of memory coherence compared to NIC. This suggests that both interventions enhanced the extent to which the narratives were oriented in space and time. However, contrary to our expectations, neither EMDR nor ImRs resulted in significant changes in the total disorganization score, global disorganization score, or self-rated memory disorganization compared to NIC:

The observed increase in contextual coherence, despite the lack of consistent changes across disorganization measures, suggests that EMDR and ImRs may have enhanced memory organization primarily on a conceptual rather than on a structural level (see also Kindt et al., 2007). This interpretation aligns with theoretical models and previous findings suggesting that these interventions may particularly foster conceptual processing (Kindt et al. 2007).

Interestingly, although no significant group differences emerged in most disorganization measures, we observed a significant increase in repetitions in the ImRs group compared to NIC when examining the disorganization indices separately. Foa et al. (1995) suggested that a high number of repetitions might indicate poor memory quality due to insufficient memory processing, based on their observation that patients who did not benefit from PE treatment exhibited more repetitions than those who did. However, our findings challenge the notion that this may also apply for ImRs, given that ImRs was the only intervention to significantly reduce the number of intrusions, intrusion distress, and intrusion load compared to NIC, despite being associated with an increase in repetitions.

Overall, our findings challenge concerns that changes in certain dimensions of memory quality, such as the reduced emotional intensity and vividness observed after EMDR and ImRs in prior studies, might negatively impact memory organization or coherence (e.g., Meckling et al., 2024). Instead, our results rather align with theoretical models proposing that trauma-focused interventions should facilitate the contextualization of fragmented trauma memories, thereby improving memory quality (Brewin, 2014; Brewin et al., 2010). Specifically, Brewin et al. (2010) pointed out that the reduction in emotional intensity and vividness of memories following ImRs and EMDR may allow patients to focus more easily on the memory, thereby further aiding the integration of dissociated memory representations. The observed improvements in contextual memory coherence in EMDR and ImRs may reflect such improvements in memory integration.

However, it is important to note that improvements in memory coherence after EMDR and ImRs were not observed across all dimensions. Neither EMDR nor ImRs associated with significant changes in the “theme” dimension of memory coherence, and the “chronology” dimension had to be excluded from further analyses due to poor inter-rater agreement. This leaves the observed improvements in the “context” dimension as the primary basis for interpretation. The findings should therefore be approached with caution, as the reliability of ratings, even for context and theme, was only fair to moderate. We can therefore not be certain whether the observed improvements in the “context” dimension of memory coherence alone are sufficient to draw robust conclusions about specific intervention effects on enhanced contextual understanding of the memory. More research is clearly needed to better understand the distinct effects of these interventions on different dimensions of memory quality.

Memory consistency. Our exploratory analyses on memory consistency yielded mixed results. No significant group differences were observed regarding the number of omissions or the number of contradictions. However, participants in the IE group made more additions to their narratives than participants in the NIC group. The increase in details after IE aligns with findings from previous studies. For example, Foa et al. (1995) found that PTSD patients produced significantly longer and more detailed narratives following PE treatment. Additionally, the observation that significantly more details were reported after IE, but not after ImRs, corresponds with prior literature demonstrating distinct effects of these two interventions on memory recall as assessed in free recall tasks. For instance, Romano et al. (2020) observed an increase in both positive and negative memory details after IE, whereas ImRs led to an increase in positive details only. During IE, participants are encouraged to recall and elaborate on all details of their memories. In contrast, ImRs and EMDR involve reactivating only specific portions of the memory prior to the rescripting phase in ImRs and the desensitization phase in EMDR. This may enhance the recall of those specific memory details addressed during the intervention, which may explain why more details were observed after IE, but not after EMDR and ImRs. Another explanation could be that the focus on reactivating specific memory elements in EMDR and ImRs might have led participants to believe that focusing on certain details during recall was more critical than recalling the entire memory in detail. In contrast, the repeated recounting of the entire memory during IE may have created an expectation that providing a more complete narrative was required. This difference in intervention instructions might have influenced participants' recall behavior in the free recall task, contributing to the increased number of additions in IE. However, further research is needed to determine precisely which details were added during IE, as our study design does not allow for such specific evaluation.

The absence of significant intervention effects on omissions or contradictions is reassuring from a clinical perspective, given that imagery-based trauma-focused interventions, particularly ImRs and EMDR, have been suspected of impairing memory or even inducing false memories. The observed pattern of results suggests that the interventions did not generally impair the participants' ability to retrieve specific memory details or alter the content of those details.

This interpretation aligns with previous research on ImRs and IE which consistently found no detrimental effects on the accuracy of experimentally induced memories in both cued recall tasks (e.g., Aleksic et al., 2024; Ganslmeier et al., 2022; Ganslmeier, et al., 2023; Hagenaars & Arntz, 2012; Reineck et al., in prep; Siegesleitner et al., 2019) and free recall tasks (Ganslmeier et al., 2022; 2023). Moreover, our findings align with previous studies that found an increase in correctly recalled details, without an increase in incorrectly recalled details of an experimentally induced memory, after both IE (Ganslmeier et al., 2023) and ImRs (Ganslmeier et al., 2022) in free recall tasks. Regarding EMDR, our results are consistent with previous studies that failed to find an increase in false memories following eye movements conducted during memory recall (Aleksic et al., in prep; Calvillo & Emami, 2019; Kevin van Schie & Leer, 2019).

Several factors might explain why we did not observe a significant increase in contradictions or omissions in the intervention groups, although they contain components that could theoretically increase the risk of memory distortions, such as imagination or the introduction of counterfactual information. For instance, participants in ImRs were transparently informed that memory modifications were part of the intervention. Similarly, participants in EMDR were informed that memories might transform during the intervention. This contrasts with typical misinformation or false memory studies, where participants are often unaware of memory manipulation and the misinformation is presented subtly (e.g., Loftus, 1997; Stark et al., 2010). Prior research has shown that the likelihood of forming false memories decreases when individuals are warned about potential misinformation (e.g., Greene et al., 1982; Karanian et al., 2020).

Nonetheless, it is important to acknowledge that our findings do not allow to draw definitive conclusions about the impact of these interventions on memory accuracy. For instance, we can not determine whether newly added details observed after IE were accurate or inaccurate, nor do we know the nature of these added details. Future research should explore in more detail what kind of details are added following IE. In particular, for the purposes of psychological credibility assessments, it would be crucial to determine whether these additional details primarily consist of sensory impressions or represent entirely new narratives that had not been previously reported.

In summary, these findings, along with our results on memory quality, are partly consistent with the theoretical assumption that trauma-focused interventions such as EMDR, ImRs, and IE may alter the meaning and reduce the distress associated with aversive memories, without impairing or distorting memory content (e.g., Arntz, 2012; Brewin et al., 2010). Specifically, we observed reductions in distress associated with intrusive memories, as well as improvements in certain dimensions of memory quality, such as a decrease in disorganized thoughts following IE and an increase in contextual coherence after ImRs and EMDR. However, these improvements in memory quality were not consistently observed across all dimensions. Regarding memory consistency, it is reassuring that none of the interventions led to significant increases in omissions or contradictions. However, it remains unclear what kinds of details were added following IE. This pattern of findings underscores the importance of further research to better understand how these interventions differentially affect specific aspects of voluntary memory, including consistency and coherence, as well as to investigate the mechanisms underlying these effects.

Strengths, limitations and future directions

Our study has several important strengths. First, although distinct effects of trauma-focused interventions on voluntary vs. involuntary memories are favorable, both from a clinical and from a legal psychological perspective, there has only been limited research systematically investigating whether trauma-focused interventions produce such selective effects. Our study addressed this gap by examining the distinct effects of three well-established trauma-focused interventions, ImRs, EMDR, and IE, on different aspects of both voluntary and involuntary memories of an aversive autobiographical event. By comparing all three interventions within a single experimental design and employing a multimethod approach – including subjective and objective measures of involuntary and voluntary memory – we aimed to achieve a comprehensive understanding of how these interventions influence different memory aspects.

Third, by assessing intervention effects on memory consistency, our study directly addresses clinically and legally relevant concerns about potential memory-distorting effects of imagery-based interventions. By examining their impact on autobiographical memories, we extend prior research, which has often relied on the assessment of experimentally induced memories that differ significantly from autobiographical memories in terms of complexity, emotional significance, and the time interval between event and intervention. In addition, as trauma survivors who serve as eyewitnesses in criminal proceedings are often required to provide a detailed verbal account of the event as part of their testimony, the use of a free recall task to assess intervention effects on memory consistency may have improved the external validity and generalizability of our findings compared to most previous studies which have relied on cued recall tasks to assess memory accuracy.

Despite these strengths, several limitations of the present study should be considered when interpreting the results. First, although we improved external validity compared to previous research by examining intervention effects on aversive autobiographical memories, our results were obtained from a healthy sample. Therefore, the question remains how well these results would generalize to clinical populations with PTSD or other trauma-related disorders and to real traumatic memories. Importantly, as Bedard-Gilligan (2017) noted, several factors, such as trauma severity, time elapsed since the trauma, emotional distress, dissociation, and cognitive ability, may significantly affect the quality of trauma narratives in clinical populations. In addition, several variables, such as depressive symptoms (e.g., Brennen et al., 2007; Johnson et al., 1993), dissociation (e.g., Porter et al., 2008), and arousal (Corson & Verrier, 2007) have been found to increase the susceptibility to memory distortions, which might be relevant with regard to our consistency outcomes.

Additionally, the relative mildness of the memories investigated in this study may have limited our ability to detect significant intervention effects. For example, the low number of intrusions recorded prior to the intervention may have reduced our ability to detect changes in intrusion frequency. Future studies should consider to define a minimum number of intrusions in the week prior to study participation to ensure a more sensitive assessment of intervention effects (see for example Ramineni et al., 2023). Furthermore, given the non-clinical sample and the mild nature of the memories, the memories examined in our study were likely already well-organized and coherent at baseline, leaving little room for the improvements in memory quality that clinical theories predict.

Second, we assessed the effects of one single intervention session over a relatively short follow-up period. We can therefore not determine whether the observed effects on both involuntary and voluntary memory would persist over time or whether different results would have emerged with a higher number of intervention sessions or a bigger time-delay between intervention and assessment.

Fourth, there were challenges in achieving good inter-rater reliability for memory coherence measures, despite intensive training and regular supervision sessions. Future studies might benefit from additional rater training or further refinement of the measures used to assess memory coherence. As such, conclusions about the specific effects of EMDR and ImRs on memory coherence, particularly in terms of improving contextual understanding, remain tentative and in need of replication to draw more robust conclusions.

Finally, we did not examine which specific memory details were added or omitted during free recall following the intervention. Future studies should try to examine this in more detail to better understand how these interventions influence memory content. For instance, it might be interesting to examine whether the interventions have differential effects on peripheral versus central details. Meckling et al. (2024), for instance, suggested that memories of peripheral details tend to be less clear and might therefore be more susceptible to distortions, as gaps in these memories may more easily unintentionally be filled in.

Conclusion

The present study contributes to our understanding of how different trauma-focused interventions, namely ImRs, EMDR and IE, affect both involuntary and voluntary recall of aversive autobiographical memories. Our findings suggest that while these interventions are effective in reducing distress associated with intrusive memories, they may do so without compromising the validity of memory content as for two of the three trauma-focused interventions examined (ImRs and EMDR), no significant differences were observed compared to the control group. The accuracy of the additional details reported after IE remains uncertain and cannot be definitively assessed at this time. Nevertheless, this challenges recent concerns that trauma-focused interventions, particularly those involving imagery or rescripting techniques, inherently carry a risk of distorting memory. Furthermore, although our findings are consistent with previous studies suggesting that improvements in memory organization or coherence may not be essential for recovery, further research is needed to better understand the specific ways in which these interventions affect different memory systems, particularly in clinical populations. Although ImRs, EMDR and IE target similar therapeutic outcomes, their different effects on memory coherence and organization suggest that they may do so through distinct mechanisms. Future research should try to investigate these mechanisms more systematically, particularly in clinical populations, to better understand how these interventions facilitate symptom reduction. In summary, further research is needed to better understand the specific mechanisms by which different trauma-focused interventions affect different dimensions of memory quality and consistency and how these processes contribute to therapeutic outcomes.

Transparency

Conflict of interest

MA, AK, TE, and LW have no conflicts of interest to disclose.

Author contributions

Conceptualization: A. Kunze, M. Aleksic, L. Wolkenstein, T. Ehring; Methodology: A. Kunze, M. Aleksic, L. Wolkenstein, T. Ehring, Y. Han, H. Funk; Software (Online-Platform for experimental design): M. Aleksic; Investigation: M. Aleksic;

Project administration: M. Aleksic; Formal analysis: M. Aleksic, Y. Han; Writing – original draft: M. Aleksic; Writing – review and editing: M. Aleksic, Wolkenstein, T. Ehring, Y. Han, H. Funk; Visualization: M. Aleksic; Supervision: L. Wolkenstein, T. Ehring, A. Kunze. All authors approved the final version of the manuscript for submission.

Declaration of generative AI in scientific writing

During the preparation of this work the author used ChatGPT and DeepL for proofreading in order to improve readability and language. After using this tool/service, the author reviewed and edited the content as needed and takes full responsibility for the content of the publication.

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Preregistration

The hypotheses, study design and analysis plan of this study were preregistered at the Open Science Framework (https://osf.io/tnkr7/).

Data Availability Statement

Anonymized data, codes and study materials have been made publicly available via the Open Science Framework and can be accessed at (https://osf.io/tnkr7/). The design and analysis plan for the experiment were preregistered at OSF and can be accessed at (https://osf.io/ekyvm).

Ethical approval

The study was carried out in accordance with the provisions of the World Medical Association Declaration of Helsinki and approved by the local Research Ethics Committee of the Department of Psychology at LMU Munich (17_Ehring_b). All participants provided written informed consent.

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References Study III

Aleksic, M., Reineck, A., Ehring, T., & Wolkenstein, L. (2024). When does imagery rescripting become a double-edged sword? - Investigating the risk of memory distortion through imagery rescripting in an online Trauma film study. *Behaviour Research and Therapy*, *174*, 104495. https://doi.org/10.1016/j.brat.2024.104495

Aleksic, M., Ehring, T., Kunze, A., & Wolkenstein, L. Does treating emotional memories come at a price? Comparing the effects of Imagery Rescripting, Eye Movement Desensitization and Reprocessing and Imaginal Exposure on memory accuracy. [Manuscript submitted for publication].

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Arlington, VA: American Psychiatric Publishing.

Arntz, A. (2012). Imagery Rescripting as a Therapeutic Technique: Review of Clinical Trials, Basic Studies, and Research Agenda. *Journal of Experimental Psychopathology*, *3*(2), 189–208. https://doi.org/10.5127/jep.024211

Arntz, A., & Weertman, A. (1999). Treatment of childhood memories: Theory and practice. *Behaviour research and therapy*, *37*(8), 715-740.

Bedard-Gilligan, M., Zoellner, L. A., & Feeny, N. C. (2017). Is Trauma Memory Special? Trauma Narrative Fragmentation in PTSD: Effects of Treatment and Response. *Clinical Psychological Science*, *5*(2), 212–225. https://doi.org/10.1177/2167702616676581

Bisson, J. I., Ehlers, A., Matthews, R., Pilling, S., Richards, D., & Turner, S. (2007). Psychological treatments for chronic post-traumatic stress disorder: Systematic review and meta-analysis. *British Journal of Psychiatry*, *190*(FEB.), 97–104. https://doi.org/10.1192/bjp.bp.106.021402

Blechert, J., Peyk, P., Liedlgruber, M., & Wilhelm, F. H. (2016). ANSLAB: Integrated multichannel peripheral biosignal processing in psychophysiological science. *Behavior Research Methods*, *48*, 1528-1545.

Boterhoven De Haan, K. L., Lee, C. W., Fassbinder, E., Van Es, S. M., Menninga, S., Meewisse, M. L., Rijkeboer, M., Kousemaker, M., & Arntz, A. (2020). Imagery rescripting and eye movement desensitisation and reprocessing as treatment for adults with post-traumatic stress disorder from childhood trauma: Randomised clinical trial. *British Journal of Psychiatry*, *217*(5), 609–615. https://doi.org/10.1192/bjp.2020.158

Boucsein, W. (2012). *Principles of Electrodermal Phenomena*. In: Electrodermal Activity. Springer, Boston, MA. https://doi.org/10.1007/978-1-4614-1126-0_1

Brennen, T., Dybdahl, R., & Kapidžić, A. (2007). Trauma-related and neutral false memories in war-induced Posttraumatic Stress Disorder. *Consciousness and Cognition*, *16*(4), 877–885. https://doi.org/10.1016/j.concog.2006.06.012

Brewin, C. R. (2007). Autobiographical memory for trauma: Update on four controversies. *Memory*, *15*(3), 227–248. https://doi.org/10.1080/09658210701256423

Brewin, C. R. (2014). Episodic memory, perceptual memory, and their interaction: Foundations for a theory of posttraumatic stress disorder. *Psychological Bulletin*, *140*(1), 69–97. https://doi.org/10.1037/a0033722

Brewin, C. R., Dalgleish, T., & Joseph, S. (1996). A dual representation theory of

Posttraumatic Stress Disorder. *Psychological Review*, *103*(4), 670–686. https://doi.org/10.1037/0033-295X.103.4.670

Brewin, C. R., Gregory, J. D., Lipton, M., & Burgess, N. (2010). Intrusive Images in Psychological Disorders: Characteristics, Neural Mechanisms, and Treatment Implications. *Psychological Review*, *117*(1), 210–232. https://doi.org/10.1037/a0018113

Calvillo, Dustin P., and Ashley S. Emami. "Do lateral eye movements increase susceptibility to misinformation? A registered replication." *Psychonomic bulletin & review 26*, 1905–1910 (2019). https://doi.org/10.3758/s13423-019-01641-6

Cooper, A. A., Clifton, E. G., & Feeny, N. C. (2017). An Empirical Review of Potential Mediators and Mechanisms of Prolonged Exposure Therapy. *Clinical Psychology Review*, *56*, 106–121. https://doi.org/doi:10.1016/j.cpr.2017.07.003

Corson, Y., & Verrier, N. (2007). Emotions and False Memories. *Psychological Science, 18*(3), 208–211. https://doi.org/10.1111/j.1467-9280.2007.01874.

Crespo, M., & Fernandez-Lansac, V. (2016). Memory and Narrative of Traumatic Events: A Literature Review. *Psychological Trauma: Theory, Research, Practice, and Policy*, *8*(2), 149–156. https://doi.org/10.1037/tra0000041

Cusack, K., Jonas, D. E., Forneris, C. A., Wines, C., Sonis, J., Middleton, J. C., ... & Gaynes, B. N. (2016). Psychological treatments for adults with posttraumatic stress disorder: A systematic review and meta-analysis. *Clinical psychology review*, *43*, 128-141.

Danböck, S. K., Rattel, J. A., Franke, L. K., Liedlgruber, M., Miedl, S. F., & Wilhelm, F. H. (2021). Peritraumatic dissociation revisited: associations with autonomic activation, facial movements, staring, and intrusion formation. *European Journal of Psychotraumatology*, *12*(1). https://doi.org/10.1080/20008198.2021.1991609

Ehlers, A., Hackmann, A., & Michael, T. (2004). Intrusive re-experiencing in post-traumatic stress disorder: Phenomenology, theory, and therapy. *Memory*, *12*(4), 403–415. https://doi.org/10.1080/09658210444000025

Fleiss, J. L., Levin, B., Paik, C. P., & Shewart, W. A. (2004). Wings. The measurement of interrater agreement. *Statistical methods for rates and proportions*, 598-626.

Foa, E. B., Dancu, C. V., Hembree, E. A., Jaycox, L. H., Meadows, E. A., & Street, G. P. (1999). A comparison of exposure therapy, stress inoculation training, and their combination for reducing posttraumatic stress disorder in female assault victims. *Journal of Consulting and Clinical Psychology*, *67*(2), 194–200. https://doi.org/10.1037//0022-006x.67.2.194

Foa, E. B., Molnar, C., & Cashman, L. (1995). Change in rape narratives during exposure therapy for posttraumatic stress disorder. *Journal of Traumatic Stress*, *8*(4), 675–690. https://doi.org/10.1007/BF02102894

Ganslmeier, M., Ehring, T., & Wolkenstein, L. (2023). Effects of imagery rescripting and imaginal exposure on voluntary memory. *Behaviour Research and Therapy*, *170*, 104409. https://doi.org/10.1016/j.brat.2023.104409

Ganslmeier, M., Kunze, A. E., Ehring, T., & Wolkenstein, L. (2022). The dilemma of trauma-focused therapy: effects of imagery rescripting on voluntary memory. *Psychological Research, 0123456789*. https://doi.org/10.1007/s00426-022-01746-z

Ganslmeier, M., Kunze, A. E., Ehring, T., & Wolkenstein, L. (2023). The dilemma of trauma-focused therapy: effects of imagery rescripting on voluntary memory. *Psychological Research*, *87*(5), 1616–1631. https://doi.org/10.1007/s00426-022-01746-z

Garry, M., Manning, C. G., Loftus, E. F., & Sherman, S. J. (1996). Imagination inflation: Imagining a childhood event inflates confidence that it occurred. *Psychonomic Bulletin and Review, 3*(2), 208–214. https://doi.org/10.3758/BF03212420

Goff, L. M., & Roediger, H. L. (1998). Imagination inflation for action events: Repeated imaginings lead to illusory recollections. *Memory and Cognition*, *26*(1), 20–33. https://doi.org/10.3758/BF03211367

Golkar, A., Tjaden, C., & Kindt, M. (2017). Vicarious extinction learning during reconsolidation neutralizes fear memory. *Behaviour Research and Therapy*. https://doi.org/10.1016/j.brat.2017.02.004

Gramann, K., & Schandry, R. (2009). *Psychophysiologie*.

Greene, E., Flynn, M. S., & Loftus, E. F. (1982). Inducing resistance to misleading information. *Journal of Verbal Learning and Verbal Behavior*, *21*(2), 207–219. https://doi.org/10.1016/S0022-5371(82)90571-0

Hagenaars, M. A., & Arntz, A. (2012). Reduced intrusion development after post-trauma imagery rescripting; An experimental study. *Journal of Behavior Therapy and Experimental Psychiatry*, *43*(2), 808–814. https://doi.org/10.1016/j.jbtep.2011.09.005

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

Holmes, E. A., Brewin, C. R., & Hennessy, R. G. (2004). Trauma Films, Information Processing, and Intrusive Memory Development. *Journal of Experimental Psychology: General*, *133*(1), 3–22. https://doi.org/10.1037/0096-3445.133.1.3

Holmes, E. A., Lang, T. J., & Shah, D. M. (2009). Developing Interpretation Bias Modification as a "Cognitive Vaccine" for Depressed Mood: Imagining Positive Events Makes You Feel Better Than Thinking About Them Verbally. *Journal of Abnormal Psychology*, *118*(1), 76–88. https://doi.org/10.1037/a0012590

Holmes, E. A., & Mathews, A. (2010). Mental imagery in emotion and emotional disorders. *Clinical Psychology Review*, *30*(3), 349–362. https://doi.org/10.1016/j.cpr.2010.01.001

Houben, S. T., Otgaar, H., Roelofs, J., & Merckelbach, H. (2018). Lateral eye movements increase false memory rates. *Clinical Psychological Science*, *6*(4), 610-616.

Houben, S. T. L., Otgaar, H., Roelofs, J., Smeets, T., & Merckelbach, H. (2020). Increases of correct memories and spontaneous false memories due to eye movements when memories are retrieved after a time delay. *Behaviour Research and Therapy*, *125*(2020), 103546. https://doi.org/10.1016/j.brat.2019.103546

Jaeger, J., Lindblom, K. M., Parker-Guilbert, K., & Zoellner, L. A. (2014). Trauma narratives: It's what you say, not how you say it. *Psychological Trauma: Theory, Research, Practice, and Policy*, *6*(5), 473–481. https://doi.org/10.1037/a0035239

James, E. L., Bonsall, M. B., Hoppitt, L., Tunbridge, E. M., Geddes, J. R., Milton, A. L., & Holmes, E. A. (2015). Computer Game Play Reduces Intrusive Memories of Experimental Trauma via Reconsolidation-Update Mechanisms. *Psychological Science*, *26*(8), 1201–1215. https://doi.org/10.1177/0956797615583071

Jelinek, L., Randjbar, S., Seifert, D., Kellner, M., & Moritz, S. (2009). The Organization of Autobiographical and Nonautobiographical Memory in Posttraumatic Stress Disorder (PTSD). *Journal of Abnormal Psychology*, *118*(2), 288–298. https://doi.org/10.1037/a0015633

Jelinek, L., Stockbauer, C., Randjbar, S., Kellner, M., Ehring, T., & Moritz, S. (2010). Characteristics and organization of the worst moment of trauma memories in posttraumatic stress disorder. *Behaviour Research and Therapy*, *48*(7), 680–685. https://doi.org/10.1016/j.brat.2010.03.014

Johnson, M. K., Hashtroudi, S., & Lindsay, D. S. (1993). Source monitoring. *Psychological bulletin, 114*(1), 3.

Karanian, J. M., Rabb, N., Wulff, A. N., Torrance, M. G., Thomas, A. K., & Race, E. (2020). Protecting memory from misinformation: Warnings modulate cortical reinstatement during memory retrieval. *Proceedings of the National Academy of Sciences of the United States of America*, *117*(37), 22771–22779. https://doi.org/10.1073/pnas.2008595117

Kindt, M., Buck, N., Arntz, A., & Soeter, M. (2007a). Perceptual and conceptual processing as predictors of treatment outcome in PTSD. *Journal of Behavior Therapy and Experimental Psychiatry*, *38*(4), 491–506. https://doi.org/10.1016/j.jbtep.2007.10.002

Kindt, M., Buck, N., Arntz, A., & Soeter, M. (2007b). Perceptual and conceptual processing as predictors of treatment outcome in PTSD. *Journal of Behavior Therapy and Experimental Psychiatry*, *38*(4), 491–506. https://doi.org/10.1016/j.jbtep.2007.10.002

Kindt, M., Soeter, M., & Vervliet, B. (2009). Beyond extinction: Erasing human fear responses and preventing the return of fear. *Nature Neuroscience*, *12*(3), 256–258. https://doi.org/10.1038/nn.2271

Kip, A., Schoppe, L., Arntz, A., & Morina, N. (2023). Efficacy of imagery rescripting in treating mental disorders associated with aversive memories-an updated meta-analysis. *Journal of Anxiety Disorders*, 102772.

https://doi.org/10.1016/j.janxdis.2023.102772

Kunze, A. E., Arntz, A., Morina, N., Kindt, M., & Lancee, J. (2017). Efficacy of imagery rescripting and imaginal exposure for nightmares: A randomized wait-list controlled trial. *Behaviour Research and Therapy*, *97*, 14–25. https://doi.org/10.1016/j.brat.2017.06.005

Lau-Zhu, A., Henson, R. N., & Holmes, E. A. (2019). Intrusive memories and voluntary memory of a trauma film: Differential effects of a cognitive interference task after encoding. *Journal of Experimental Psychology: General, 148*(12), 2154.

Lee, S. W., & Kwon, J. H. (2013). The efficacy of Imagery Rescripting (IR) for social phobia: A randomized controlled trial. *Journal of Behavior Therapy and Experimental Psychiatry*, *44*(4), 351–360. https://doi.org/10.1016/j.jbtep.2013.03.001

Leer, A., & Engelhard, I. M. (2020). Side effects of induced lateral eye movements during aversive ideation. *Journal of Behavior Therapy and Experimental Psychiatry*, *68*, 101566. https://doi.org/10.1016/j.jbtep.2020.101566

Leer, A., Engelhard, I. M., Lenaert, B., Struyf, D., Vervliet, B., & Hermans, D. (2017). Eye movement during recall reduces objective memory performance: An extended replication. *Behaviour Research and Therapy, 92*, 94–105. https://doi.org/10.1016/j.brat.2017.03.002

Levine, B., Svoboda, E., Hay, J. F., Winocur, G., & Moscovitch, M. (2002). Aging and autobiographical memory: Dissociating episodic from semantic retrieval. *Psychology and Aging*, *17*(4), 677–689. https://doi.org/10.1037/0882-7974.17.4.677

Loftus, E. F. (1997). Creating False Memories. *Scientific American 277 (3), 70-75.*, *277*(3), 70–75.

Loftus, E. F., Miller, D. G., & Burns, H. J. (1978). Semantic integration of verbal information into a visual memory. *Journal of Experimental Psychology: Human Learning and Memory*, *4*(1), 19–31. https://doi.org/10.1037/0278-7393.4.1.19

Lyle, K. B., & Johnson, M. K. (2007). Source misattributions may increase the accuracy of source judgments. *Memory and Cognition*, *35*(5), 1024–1033. https://doi.org/10.3758/BF03193475

Maxfield, L., Melnyk, W. T., & Hayman, G. C. A. (2008). A Working Memory Explanation for the Effects of Eye Movements in EMDR. *Journal of EMDR Practice and Research*, *2*(4), 247–261. https://doi.org/10.1891/1933-3196.2.4.247

Mazzoni, G., & Memon, A. (2003). Imagination can create false autobiographical memories. *Psychological Science*, *14*(2), 186–188. https://doi.org/10.1046/j.1432-1327.2000.01821.x

Meckling, H. I., Nauta, M. H., van Hout, W. J. P. J., & Wessel, I. (2024). The effects of eye movements on the content and characteristics of unpleasant autobiographical memories: an extended replication study. *Memory*, 1–19. https://doi.org/10.1080/09658211.2024.2307925

Michael, T., Ehlers, A., Halligan, S. L., & Clark, D. M. (2005). Unwanted memories of assault: What intrusion characteristics are associated with PTSD? *Behaviour Research and Therapy*, *43*(5), 613–628. https://doi.org/10.1016/j.brat.2004.04.006

Morina, N., Lancee, J., & Arntz, A. (2017). Imagery rescripting as a clinical intervention for aversive memories: A meta-analysis. *Journal of Behavior Therapy and Experimental Psychiatry, 55*, 6–15. https://doi.org/10.1016/j.jbtep.2016.11.003

Otgaar, H., Houben, S. T. L., Rassin, E., & Merckelbach, H. (2021). Memory and eye movement desensitization and reprocessing therapy: a potentially risky combination in the courtroom. *Memory*, *29*(9), 1254–1262. https://doi.org/10.1080/09658211.2021.1966043

Porter, S., Taylor, K., & ten Brinke, L. (2008). Memory for media: Investigation of false memories for negatively and positively charged public events. *Memory*, *16*(6), 658–666. https://doi.org/10.1080/09658210802154626

Rameckers, S. A., Emmerik, A. A. P. Van, Boterhoven, K., Haan, D., Kousemaker, M., Fassbinder, E., Lee, C. W., Meewisse, M., Menninga, S., Rijkeboer, M., Schaich, A., & Arntz, A. (2024). Behaviour Research and Therapy The working mechanisms of imagery rescripting and eye movement desensitization and reprocessing : Findings from a randomised controlled trial. *Behaviour Research and Therapy*, *175*, 104492. https://doi.org/10.1016/j.brat.2024.104492

Ramineni, V., Millroth, P., Iyadurai, L., Jaki, T., Kingslake, J., Highfield, J., Summers, C., Bonsall, M. B., & Holmes, E. A. (2023). Treating intrusive memories after trauma in healthcare workers: a Bayesian adaptive randomised trial developing an imagery-competing task intervention. *Molecular Psychiatry*, *September 2022*, 1–10. https://doi.org/10.1038/s41380-023-02062-7

Rattel, J. A., Danböck, S., Miedl, S. F., Liedlgruber, M., & Wilhelm, F. H. (2024). Hitting the Rewind Button: Imagining Analogue Trauma Memories in Reverse Reduces Distressing Intrusions. *Cognitive Therapy and Research*, *48*(5), 932–943. https://doi.org/10.1007/s10608-024-10488-8

Rattel, J. A., Miedl, S. F., Franke, L. K., Grünberger, L. M., Blechert, J., Kronbichler, M., Spoormaker, V. I., & Wilhelm, F. H. (2019). Peritraumatic Neural Processing and Intrusive Memories: The Role of Lifetime Adversity. *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging*, *4*(4), 381–389. https://doi.org/10.1016/j.bpsc.2018.12.010

Reese, E., Haden, C. A., Baker-Ward, L., Bauer, P., Fivush, R., & Ornstein, P. A. (2011). Coherence of Personal Narratives Across the Lifespan: A Multidimensional Model and Coding Method. *Journal of Cognition and Development*, *12*(4), 424–462. https://doi.org/10.1080/15248372.2011.587854

Reineck, A., Aleksic, M., Ehring, T., & Wolkenstein, L. Does the plausibility of the script in imagery rescripting for aversive, experimentally induced memory cause memory accuracy impairment and false memory production?[Manuscript in preparation].

Romano, M., Moscovitch, D. A., Huppert, J. D., Reimer, S. G., & Moscovitch, M. (2020). The effects of imagery rescripting on memory outcomes in social anxiety disorder. *Journal of Anxiety Disorders*, *69*, 102169. https://doi.org/10.1016/j.janxdis.2019.102169

Rubin, D. C., Deffle, S. A., Ogle, C. M., Dowell, N. M., Graesser, A. C., & Beckham, J. C. (2016). Participant, rater, and computer measures of coherence in posttraumatic stress disorder. *Journal of Abnormal Psychology*, *125*(1), 11–25. https://doi.org/10.1037/abn0000126

Schlagman, S., & Kvavilashvili, L. (2008). Involuntary autobiographical memories in and outside the laboratory: How different are they from voluntary autobiographical memories? *Memory and Cognition*, *36*(5), 920–932. https://doi.org/10.3758/MC.36.5.920

Scoboria, A., Wade, K. A., Lindsay, D. S., Azad, T., Strange, D., Ost, J., & Hyman, I. E. (2017). A mega-analysis of memory reports from eight peer-reviewed false memory implantation studies. *Memory*, *25*(2), 146–163. https://doi.org/10.1080/09658211.2016.1260747

Sevenster, D., Beckers, T., & Kindt, M. (2013). Prediction error governs pharmacologically induced amnesia for learned fear. *Science*, *339*(6121), 830–833. https://doi.org/10.1126/science.1231357

Shapiro, F. (2017). *Eye movement desensitization and reprocessing (EMDR) therapy: Basic principles, protocols, and procedures.* Guilford Publications.

Siegesleitner, M., Strohm, M., Wittekind, C. E., Ehring, T., & Kunze, A. E. (2019). Effects of imagery rescripting on consolidated memories of an aversive film. *Journal of Behavior Therapy and Experimental Psychiatry*, *62*, 22–29. https://doi.org/10.1016/j.jbtep.2018.08.007

Smeets, T., Candel, I., & Merckelbach, H. (2004). Accuracy, completeness, and consistency of emotional memories. *American Journal of Psychology*, *117*(4), 595–609. https://doi.org/10.2307/4148994

Stark, C. E. L., Okado, Y., & Loftus, E. F. (2010). Imaging the reconstruction of true and false memories using sensory reactivation and the misinformation paradigms. *Learning and Memory*, *17*(10), 485–488. https://doi.org/10.1101/lm.1845710

Steil, R., & Ehlers, A. (2000). Dysfunctional meaning of posttraumatic intrusions in chronic PTSD. *Behaviour Research and Therapy*, *38*(6), 537–558. https://doi.org/10.1016/S0005-7967(99)00069-8

Stickgold, R. (2005). Sleep-dependent memory consolidation. *Nature*, *437*(7063), 1272–1278. https://doi.org/10.1038/nature04286

Strohm, M., Siegesleitner, M., Kunze, A. E., Ehring, T., & Wittekind, C. E. (2019). Imagery Rescripting of Aversive Autobiographical Memories: Effects on Memory Distress, Emotions, and Feelings of Mastery. *Cognitive Therapy and Research*, *43*(6), 1005–1017. https://doi.org/10.1007/s10608-019-10021-2

Strohm, M., Siegesleitner, M., Kunze, A. E., Werner, G. G., Ehring, T., & Wittekind, C. E. (2021). Psychological and Physiological Effects of Imagery Rescripting for Aversive Autobiographical Memories. *Cognitive Therapy and Research*, *45*(6), 1093–1104. https://doi.org/10.1007/s10608-021-10233-5

Van Den Hout, M., Muris, P., Salemink, E., & Kindt, M. (2001). Autobiographical memories become less vivid and emotional after eye movements. *British Journal of Clinical Psychology*, *40*(2), 121–130. https://doi.org/10.1348/014466501163571

Van Minnen, A., Wessel, I., Dijkstra, T., & Roelofs, K. (2002). Changes in PTSD patients' narratives during prolonged exposure therapy: A replication and extension. *Journal of Traumatic Stress*, *15*(3), 255–258. https://doi.org/10.1023/A:1015263513654

van Schie, K., van Veen, S. C., & Hagenaars, M. A. (2019). The effects of dual-tasks on intrusive memories following analogue trauma. *Behaviour Research and Therapy*, *120*, 103448. https://doi.org/10.1016/j.brat.2019.103448

van Schie, Kevin, & Leer, A. (2019). Lateral Eye Movements Do Not Increase False-Memory Rates: A Failed Direct-Replication Study. *Clinical Psychological Science*, *7*(5), 1159–1167. https://doi.org/10.1177/2167702619859335

Vehtari, A., Gelman, A., & Gabry, J. (2017). Practical Bayesian model evaluation using leave-one-out cross-validation and WAIC. *Statistics and computing*, *27*, 1413-1432.

Visser, R. M., Lau-Zhu, A., Henson, R. N., & Holmes, E. A. (2018). Multiple memory systems, multiple time points: How science can inform treatment to control the expression of unwanted emotional memories. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *373*(1742). https://doi.org/10.1098/rstb.2017.0209

Watts, B. V., Schnurr, P. P., Mayo, L., Young-Xu, Y., Weeks, W. B., & Friedman, M. J. (2013). Meta-analysis of the efficacy of treatments for posttraumatic stress disorder. *Journal of Clinical Psychiatry*, *74*(6), 541–550. https://doi.org/10.4088/JCP.12r08225

Wegerer, M., Blechert, J., Kerschbaum, H., & Wilhelm, F. H. (2013). Relationship between fear conditionability and aversive memories: evidence from a novel conditioned-intrusion paradigm. *PloS one*, *8*(11), e79025.

Zetsche, U., Ehring, T., & Ehlers, A. (2009). The effects of rumination on mood and intrusive memories after exposure to traumatic material: An experimental study. *Journal of Behavior Therapy and Experimental Psychiatry*, *40*(4), 499–514. https://doi.org/10.1016/j.jbtep.2009.07.001

5 General Discussion

This thesis aimed to enhance our understanding of how IE, EMDR, and ImRs affect the retrieval of distressing emotional memories, with a focus on both involuntary and voluntary memory retrieval. Clinical theories emphasize the role of psychological interventions in reducing intrusive memories and improving voluntary recall, while legal psychology highlights concerns about their potential to compromise the factual accuracy of voluntary memory. To address these contrasting perspectives, the first objective was to examine the impact of IE, EMDR and ImRs on experimentally induced memories, which allowed control over memory content and assessment of memory accuracy (*Studies I* and *II*). Additionally, *Study II* aimed to model and evaluate potential risk factors that might increase the likelihood of memory distortions in clinical settings. The second objective was to extend the investigation to autobiographical memories, enhancing the generalizability of findings to real-world settings, where interventions typically target distressing personal memories rather than experimentally induced memories. *Study III* therefore examined the intervention effects on both the quality (i.e., disorganization, coherence) and consistency of voluntary recall, as well as intrusive memories associated with distressing autobiographical events. This chapter summarizes the key findings, situates them within the context of existing research, and discusses their implications for future research and practice. Additionally, general strengths and limitations of the studies presented in this thesis will be addressed.

5.1 Summary of Findings

Study I aimed to evaluate whether IE, EMDR, and ImRs, compared to NIC, effectively reduce the frequency and distress of involuntary aversive memories while preserving the factual accuracy of voluntary memories in a controlled experimental setting. To overcome limitations of prior research, the study utilized a standardized social stressor (TSST) to induce complex, personally relevant memories and adopted a multiple-day paradigm to evaluate intervention effects on consolidated memories. Given their demonstrated efficacy in treating PTSD, it was hypothesized that all three interventions would reduce the frequency of intrusive memories. Additionally, based on prior experimental findings, it was expected that ImRs and IE would enhance the factual accuracy of voluntary memory, whereas EMDR was anticipated to impair it. Contrary to these expectations, none of the interventions reduced the number of intrusive memories compared to NIC. However, EMDR and IE significantly reduced intrusion load (i.e., intrusion frequency weighted by distress). Regarding voluntary memory, no group differences were observed; the interventions neither improved nor impaired memory accuracy. Although these findings are reassuring from a clinical perspective, they do not rule out the possibility that specific risk factors in the clinical application of these interventions might still promote memory distortions.

Study II aimed to systematically examine potential risks factors for ImRs. Using a trauma film-paradigm, it was tested whether specific instructions during ImRs as typically provided in clinical practice (i.e., detailed imagery with a sensory focus) increase the risk of memory distortions and whether this effect depends on the quality (i.e., clarity and completeness) of the memory targeted by the intervention. This question holds important implications given that clinical practice often involves working with patients whose memories are incomplete or unclear, either due to the natural fading of memory over time or due to PTSD-related psychopathology, as described in the DSM-5 (APA, 2013, pp. 217–272). It was hypothesized that ImRs might carry a higher risk when changes to the memory are imagined in great sensory-perceptual detail, particularly in individuals whose memories are unclear or incomplete. Against our expectations, ImRs focusing on sensory-perceptual details did not evoke these effects. On the contrary, it was even associated with enhanced memory accuracy compared to NIC, independent of the completeness and clarity of the original memory. In addition, participants who received ImRs with a sensory-perceptual focus experienced the greatest reduction in subjective memory-related distress; however, contrary to our hypotheses, this was not accompanied by a decrease in the frequency of intrusive memories.

Taken together, the results of studies I and II provide no evidence to support the concern that trauma-focused interventions inherently distort factual memory content, even when examined under conditions designed to mimic clinical high-risk scenarios. However, as these studies focused on experimentally induced memories, their generalizability to autobiographical memories is limited. To address this, *study III* extended the investigation to autobiographical memories. In addition, it aimed to more comprehensively test contradictory predictions regarding the impact of IE, EMDR and ImRs on voluntary recall by exploring both their effects on memory consistency as a proxy for accuracy, and on memory coherence and disorganization, which are central to clinical theories. Given that EMDR and ImRs explicitly focus on modifying memory quality (in terms of emotionality and vividness), it was assumed that they would affect memory coherence and disorganization, but no specific direction for these effects was predicted due to the lack of prior empirical findings. In contrast, IE was not anticipated to improve memory disorganization or coherence, based on existing findings.

Results on involuntary memory revealed that, contrary to expectations, ImRs was the only intervention to significantly reduce the number of intrusive memories from pre- to post-intervention compared to NIC. Nevertheless, all intervention groups demonstrated greater reductions in intrusion load relative to NIC. Regarding the consistency of voluntary memory, none of the interventions resulted in significantly more contradictions or omissions in memory reports compared to NIC. Participants in the IE group, however, added more details to their narratives compared to those in NIC, though the accuracy of these additions remains unclear. Regarding the coherence and disorganization of voluntary memory, results were partially consistent with the predictions. In terms of memory coherence, EMDR and ImRs were associated with improvements on the "context" dimension, indicating better orientation in space and time. However, these effects did not extend to other dimensions of memory coherence (i.e., "theme", "chronology"). As anticipated, IE had no significant impact on any dimension of memory coherence. In terms of memory disorganization, neither EMDR nor ImRs affected memory disorganization on any of the disorganization indices. In contrast, IE was found to reduce disorganized thoughts as compared to NIC, but this was not accompanied by improvements on other indices of disorganization.

5.2 Integration of Results and Implications for Future Research and Practice

Taken together, these findings offer a nuanced perspective on the selective effects of IE, EMDR, and ImRs on voluntary and involuntary memory aspects. While the preceding chapters have examined the results, implications, and methodological limitations of the individual studies, the following sections aim to synthesize these findings in the context of the intended and unintended intervention effects outlined in Chapter 1. In addition, the broader implications for both future research and clinical practice will be critically evaluated.

5.2.1 Intended Memory Effects of Trauma-Focused Interventions

As outlined in Chapter 1 of this thesis, trauma-focused interventions aim to alleviate the burden of uncontrolled and involuntary retrieval of trauma memories, but to preserve or even enhance controlled, voluntary memory retrieval (see Lau-Zhu et al., 2019). According to DRT (Brewin et al., 1996; Brewin et al., 2010), trauma-focused interventions achieve this goal by integrating memory representations that are thought to be dissociated in PTSD: sensory and emotional aspects of the traumatic event, which are not voluntarily retrievable (S-reps), and contextual and semantic information of the traumatic event, which are voluntarily retrievable (C-reps). This integration is believed to enhance inhibitory control over involuntary memory retrieval while also improving voluntary access to trauma memory representations (Brewin et al., 2010). Complementing this, the Retrieval Competition Account (RCA; Brewin, 2006) suggests that the integration of S-reps and C-reps results in new, more adaptive memory representations that coexist with, rather than overwrite, the original memories. These new representations are assumed to compete with the original ones during retrieval, reducing the dominance of distressing intrusive memories.

Effects on involuntary memory

Compatibility of findings with previous research

Regarding involuntary memory retrieval, s*tudies I, II* and *III* found no significant intervention effects on the number of intrusive memories. However, they did reveal significant reductions in intrusion load (i.e., number of intrusive memories weighted for intrusion distress) following EMDR, IE (*studies I and III*), and ImRs (*study III*). The absence of intervention effects on the number of intrusive memories stands in contrast to prior research, which has reported reductions in intrusive memories following these interventions (e.g., Strohm et al., 2019; Xu et al., 2023), and it is inconsistent with their well-established clinical efficacy (e.g., Cuijpers et al., 2020; Kip et al., 2023). However, the significant reduction in intrusion load suggests that methodological factors, rather than a lack of intervention efficacy, explain the absence of effects on the frequency of intrusive memories.

One plausible explanation is the presence of floor effects: participants across all studies reported relatively few intrusive memories at baseline, limiting the sensitivity to detect changes. This limitation has been noted in prior research, where the challenge of eliciting a sufficient number of intrusive memories in analogue samples has constrained the evaluation of intervention efficacy (e.g., Siegesleitner et al., 2019). Recent experimental studies have addressed this issue by introducing intrusion load – a composite measure that accounts for both the frequency of intrusive memories and the distress they cause (e.g., Rattel et al., 2019; 2024). Our findings support the use of intrusion load as a more sensitive measure of intervention effects, particularly in analogue samples where baseline intrusion frequency is low. Moreover, since the distress caused by intrusive memories, rather than their frequency, better predicts PTSD severity and clinical outcomes (e.g., Kleim et al., 2007; Michael et al., 2005), intrusion load emerges as a clinically relevant measure. Future analogue studies should therefore adopt this measure alongside intrusion frequency to provide a more comprehensive assessment of intervention effects.

Compatibility of findings with theoretical predictions

The observed reductions in intrusion load align with predictions of DRT, which posits that contextualizing sensory-bound representations (S-reps) reduces their emotional salience and associated distress (Brewin et al., 2010). Although DRT suggests that intrusive memories should not only become less distressing but also that inhibitory control over involuntary retrieval should improve, the lack of significant effects on intrusion frequency may be explained by the methodological limitations discussed earlier.

Implications for future research

On a more general level, these findings highlight the need to refine analogue paradigms to more effectively model trauma-related memory phenomena. The trauma film paradigm, often regarded as the gold standard for studying mechanisms of PTSD and its treatment in nonclinical samples (James et al., 2016), offers high experimental control over memory content, making it particularly effective for assessing memory accuracy, which was a central focus of this thesis. However, its limitations emerge when attempting to model both involuntary and voluntary memory phenomena in ways that approximate the complexity of real-life trauma memories. As previously noted, although the trauma film paradigm has successfully elicited intrusive memories in some studies (e.g., Holmes et al., 2004), other studies have failed to induce a sufficient number of intrusions (e.g., Siegesleitner et al., 2019). Moreover, the voluntary memories it induces often lack personal relevance, emotional intensity, and immersive qualities characteristic of real-life trauma memories. These shortcomings limit its suitability to examine the differential effects of trauma-focused interventions on involuntary and voluntary memory aspects. Although Studies I and III attempted to address these limitations by employing alternative paradigms designed to enhance the complexity and emotional salience of the memories, the results suggest that these paradigms may also not have elicited sufficiently distressing or personally relevant memories to allow a thorough assessment of their effects on involuntary memory. As such, they may as well not be optimal for assessing the differential effects of trauma-focused interventions on both involuntary and voluntary memory aspects. Future research should prioritize refining analogue paradigms to better capture these aspects. For example, to enhance the likelihood of triggering relevant intrusive memories, it may be promising to tailor stimuli to participant characteristics and use content that has stronger associations with their everyday experiences. When using the trauma film paradigm, rape-related film clips, for instance, may elicit stronger associations and intrusive memories in female participants (Ganslmeier et al., 2023).

Effects on voluntary memory

The clinical literature highlights the critical role of disorganized and incoherent voluntary memories in PTSD (e.g. Brewin et al., 2010; Ehlers & Clark, 2000). According to the Dual Representation Theory (Brewin et al., 1996; 2010) and other clinical theories (e.g., Ehlers & Clark; 2000; Foa et al., 2006), effective trauma-focused interventions should lead to improvements in these aspects. However, prior empirical research directly examining their effects on memory disorganization and coherence is surprisingly limited, particularly for EMDR and ImRs.

Compatibility of findings with prior research

The findings from *Study III* indicate that the examined interventions exert distinct effects on voluntary memory quality, specifically with regard to memory coherence and disorganization. EMDR and ImRs improved memory coherence by enhancing the spatial and temporal orientation of voluntary memory reports, pointing to improvements at a conceptual level. In contrast, neither intervention significantly improved measures of memory disorganization, suggesting that improvements in the structural organization of the memory play a less central role in these interventions. Conversely, IE did not enhance memory coherence but did show an effect on reducing disorganized thoughts, pointing to modest improvements in the structural organization of the memory.

These findings are largely consistent with prior research. For ImRs, previous studies have similarly reported improvements in the temporal and spatial orientation of voluntary memories, while changes in structural organization were either limited or absent for both ImRs and EMDR (e.g., Kindt et al., 2007; Meckling et al., 2024). This supports the notion that these interventions primarily target improvements on a conceptual level rather than structural re-organization (Kindt et al., 2007). However, as the improvements observed in EMDR and ImRs were not uniform across all dimensions of memory coherence (e.g., no effects on theme and chronology) and achieving good inter-rater reliability for these measures proved challenging, no definitive conclusions can be drawn regarding their potential to enhance voluntary memory specifically at the conceptual level. Further research is needed to refine these measures and to explore how different dimensions of memory coherence contribute to symptom reduction, as well as whether these patterns are unique to EMDR and ImRs.

Similarly, the findings on IE align with earlier studies, which have shown inconsistent effects on both memory coherence and disorganization (e.g., Bedard-Gilligan et al., 2017; Foa et al., 1995; van Minnen et al., 2002). Notably, the reduction in intrusion load following IE, despite minimal changes in memory coherence or disorganization, aligns with evidence suggesting that improvements in memory organization and coherence may not be a central mechanism driving its therapeutic effects (Bedard-Gilligan et al., 2017; Cooper et al., 2017).

Compatibility of findings with theoretical assumptions

Although DRT does not explicitly predict differences in how these interventions affect voluntary memory quality, the findings can be reconciled within its framework. DRT posits that, in addition to their reliving components, EMDR and ImRs facilitate the integration of dissociated memory representations through their unique therapeutic components (Brewin et al., 2010). For example, in EMDR, bilateral stimulation (e.g., therapist’s hand movements) is hypothesized to act as a contextual cue, anchoring memory representations to the safety of the present rather than the perceived danger of the past (Brewin et al., 2010). By repeatedly linking trauma-related representations with the present, EMDR may allow a person to place past events within a clearer temporal framework. This may result in improved spatial and temporal orientation of the targeted memory as observed in study III. Similarly, DRT suggests that ImRs fosters the adaptive elaboration of C-reps by introducing positive coping imagery (Brewin et al., 2010). The positive coping imagery may help to provide a clearer distinction between old trauma-related memory representations and newly constructed adaptive images. By explicitly contrasting "then" and "now," the rescripting component may strengthen the temporal orientation of memory representations. Compared to EMDR and ImRs, IE’s focus on repeated exposure to the trauma memory provides fewer contextual cues. This may explain the lack of improvement in the temporal or spatial orientation of memories following IE.

Taken together, the mechanisms proposed by DRT offer a plausible explanation for the observed differences in memory quality across these interventions. However, these findings underscore the need to refine theoretical predictions about how trauma-focused interventions affect voluntary memory. While DRT suggests that these interventions should enhance memory organization and coherence, our findings highlight the need to differentiate between specific dimensions of these measures, examine how they respond to treatment, specify how such improvements relate to symptom reduction, and how these effects vary across interventions. Enhancing our understanding of the mechanisms underlying changes in voluntary memory is essential in order to be able to target specific processes that promote recovery and improving treatment efficacy (Kazdin et al., 2009).

Clinical Implications

Beyond these theoretical considerations, our findings hold implications for clinical practice. Clinicians often incorporate the idea of memory re-organization into treatment rationales, particularly for IE (see Bedard-Gilligan et al., 2017; Foa et al., 2007). However, if future research continues to show that trauma-focused treatments do not reliably enhance the structural organization of memories, it may be necessary to reassess how treatment goals and mechanisms are framed and communicated to patients. Unrealistic expectations about narrative reorganization could lead to disappointment or a sense of failure when such changes do not occur, potentially undermining the patients’ confidence in the therapeutic process. Along these lines, research demonstrates that patients' perceptions of therapy credibility, i.e., their belief in the logic, appropriateness, and effectiveness of a treatment, are associated with positive outcomes (Constantino et al., 2018). Likewise, it has been found that patients' belief in treatment success predicts greater reductions in PTSD symptoms in trauma-focused CBT (Matthews et al., 2022). Therefore, it appears crucial to align treatment rationales with current empirical evidence in order to mitigate the risk of treatment failures.

5.2.2 Unintended memory effects

In contrast to clinical theories suggesting that successful treatment enhances voluntary memory recall, experts in legal psychology have expressed concerns that trauma-focused interventions could inadvertently impair voluntary memory retrieval, particularly in terms of memory accuracy (e.g., Otgaar et al., 2021). To examine potential negative intervention effects on memory accuracy, previous research predominantly explored intervention effects on experimentally induced memories of simple stimuli, such as word lists, photographs, or film clips (e.g., Calvillo & Emami, 2019; Houben et al., 2020; Leer et al., 2017). These studies often focused on interventions conducted immediately after memory induction, before memory consolidation could take place (e.g., Hagenaars & Arntz, 2012; Houben et al., 2018, 2020; but see Ganslmeier et al., 2022; 2023). In addition, in the case of EMDR, prior research mostly relied on the misinformation paradigm, which introduces suggestive pressure not reflective of lege artis clinical practice (Houben et al., 2018; Leer & Engelhard, 2020). As for IE and ImRs, these prior studies consistently found no adverse effects on memory accuracy (Hagenaars & Arntz, 2012; Ganslmeier et al., 2022; 2023; Siegesleitner et al., 2019). With regard to EMDR, prior findings were more mixed with some demonstrating increased false memory rates following eye movements performed during memory recall (e.g., Houben et al., 2018; Leer & Engelhard, 2020), but others failing to replicate these results (e.g. Calvillo & Emami, 2019; van Schie & Leer, 2019). As outlined in chapter 1, these prior findings did not allow robust conclusions regarding intervention effects on more complex, emotionally charged memories that had already gone consolidation, which are typically the target in clinical treatment.

In contrast to these previous studies, *Studies I, II* and *III* of this thesis aimed to better reflect the conditions under which these interventions are typically applied in clinical settings, specifically in terms of the types of memories targeted and the therapeutic instructions commonly used in practice. The next sections will integrate and discuss their findings.

Compatibility of Results with Prior Research and Implications for Future Research

The findings of *Studies I, II,* and *III* collectively provide strong evidence that under these conditions, trauma-focused interventions, such as IE, EMDR and ImRs, do not increase the risk of memory distortions. More specifically, *study I* provided evidence that none of the interventions impaired memory accuracy for emotionally salient and personally relevant memories that have already undergone consolidation. For ImRs and IE, this aligns with and extends previous findings showing no adverse effects on memory accuracy (Hagenaars & Arntz, 2012; Ganslmeier et al., 2022; 2023; Siegesleitner et al., 2019). Regarding EMDR, the findings suggest that concerns about its potential to impair memory accuracy are largely unsupported, when the intervention is implemented in line with best clinical practice, i.e., without the use of suggestive pressure on the person undergoing treatment.

Study II extends these findings by demonstrating that ImRs does not impair memory performance, even under conditions that may be associated with an increased risk of leading to memory inaccuracies. Specifically, even when the original memory is weak - that is, unclear and incomplete - and the production of sensory-rich images is actively encouraged during the rescripting process, memory accuracy remains intact. This finding has important clinical implications, particularly for therapeutic work with patients who present with incomplete or degraded memories, which may either result from the natural fading of memory over time or stem from PTSD-related psychopathology, as described in the DSM-5 (APA, 2013, pp. 217–272). The findings of study II suggest that it is not necessary to adjust the standard ImRs protocol for these patients - such as reducing the sensory richness of imagery - to mitigate concerns about introducing risks to memory accuracy.

The results of *Study III* align with and extend the findings of Studies I and II by indicating that IE, EMDR, and ImRs do not inherently lead to memory impairments, even when applied to complex, autobiographical memories. Specifically, the absence of increased omissions or contradictions in memory reports across all interventions suggests that these these interventions neither compromise the ability to recall specific memory details nor distort their content. However, the finding that participants receiving IE added significantly more details to their memory reports compared to the no-intervention control group requires careful interpretation. Previous research on experimentally induced memories, which allowed control over memory content, consistently demonstrated no detrimental effects of IE on memory accuracy (e.g., Hagenaars & Arntz, 2012; Ganslmeier et al., 2022; 2023). Furthermore, a previous study by Ganslmeier et al. (2023) found that an increase in details following IE was limited to correctly recalled details without a corresponding increase in incorrect details for an experimentally induced memory. These prior findings suggest that the additional details observed in our study may also be accurate. However, the design of study III did not allow to directly test this assumption, leaving open the possibility that some (or all) of the added details might be inaccurate.

Against this background, it is important to consider the broader implications of any memory alterations following treatment. Although the studies presented in this thesis did not find statistically significant increases in omissions or contradictions during free recall (*Study III*) or inaccuracies during cued recall (*Studies I* and *II*) compared to no-intervention controls, even minor alterations in memory could have critical implications in legal contexts if they affect central event information. Future research should therefore move beyond merely quantifying the number of omissions, additions, and contradictions in memory reports and the number of correct answers in cued recall and instead focus on examining the nature of the details affected. For instance, it is conceivable that memory for information revisited during the intervention may be enhanced, while information ignored or altered during treatment may become less accessible. This is in line with findings on "retrieval induced forgetting" (Anderson et al., 1994), which demonstrate that the act of retrieval can alter the accessibility of information in memory, enhancing the memory of items that have been retrieved, but impairing memory of items that have not been retrieved (Murayama et al., 2014). To address this, future studies should systematically document which memory elements are revisited, ignored, or altered during the intervention and evaluate how these information evolve throughout treatment. Moreover, it is important to clarify whether memory changes primarily involve peripheral details of an event or central information. From a legal perspective, it would be particularly concerning if the added details included entire sequences of events or critical central information that had not been previously remembered, as this could raise questions about the validity of the memory reports (Federal Ministry of Justice [Germany], 2024). Future research should therefore explore whether IE, EMDR and ImRs differentially affects peripheral and central event details to better understand the implications for both therapeutic and legal contexts.

Taken together, the results of this thesis challenge concerns that trauma-focused interventions inherently increase the risk of memory distortions (Otgaar et al., 2021). As outlined in Chapter 1, such concerns are rooted in experimental evidence demonstrating the fallibility of memory, particularly in contexts involving imagination (Garry et al., 1996) or exposure to misleading information (Goff & Roediger, 1998). Based on such findings, it has been suggested that trauma-focused interventions incorporating imagination techniques and/or deliberate modifications of memory content, such as IE, EMDR, and ImRs, might similarly distort factual memory details (e.g., Otgaar et al., 2021). In Chapter 1 we questioned whether findings from experimental paradigms demonstrating memory fallibility can be generalized to trauma-focused interventions, given their substantial procedural differences.

The results of this thesis suggest that such generalizations are unwarranted and that procedural differences in trauma-focused interventions likely play a critical role in mitigating memory distortions. Specifically, unlike false memory paradigms, which typically rely on suggestive techniques to induce false memories (e.g., Loftus, 1997; Stark et al., 2010), trauma-focused interventions emphasize transparent communication of the treatment rationales. This includes explaining the use of imagery and the intentional modification of memories in the imagination (e.g., in ImRs, Arntz & Weertman, 1999) or potential changes in memories during associative processes (e.g., in EMDR, Shapiro, 2001). This transparency may act as a protective factor, similar to the "warning effect" observed in false memory research, where forewarning participants about exposure to misinformation has been shown to reduce susceptibility to memory distortions (Karanian et al., 2020; Oeberst et al., 2021). Supporting this interpretation, a recent study provided direct experimental evidence that the transparency of memory modifications in ImRs mitigates the risk of memory distortions (Reineck, Aleksic et al., in prep). Another important factor is the salience of memory modifications in trauma-focused interventions. For example, in ImRs, the entire course of events is changed in the imagination. This stands in stark contrast to the subtle manipulations used in false memory paradigms, which are often intentionally designed to go unnoticed, making them more likely to be integrated into existing memories (Leding & Antonio, 2019). Finally, our findings align with research showing that emotionally charged *(studies I -III)* and autobiographical *(study III)* memories tend to be better retained than memories of neutral events (Anderson et al., 2006) and may therefore also be less susceptible to distortion compared to the personally irrelevant and simplistic memories commonly investigated in experimental false memory paradigms (e.g., Houben et al., 2018; Leer et al., 2017)

Differential effects on intrusive and voluntary memory

From a clinical theoretical perspective, these results support the notion that intrusive memories and voluntary memories for the same material are dissociable (e.g., Deeprose et al., 2012; Lau-Zhu et al., 2019) and that trauma-focused interventions can selectively reduce the distress associated with involuntary retrieval of traumatic memories, while preserving - or even enhancing - the accuracy of voluntarily retrieved memories (e.g., Arntz, 2012; Brewin, 2010). Consistent with the predictions of the Dual Representation Theory (Brewin et al., 2010), the observed improvements in memory accuracy following ImRs in Study II and the increase in reported details following IE in Study III may reflect enhanced voluntary access to memory representations after these interventions. However, as previously discussed, the validity of the additional details observed following IE remains uncertain.

A fundamental yet unresolved question remains: What happens to the original memory following modifications induced by clinical interventions? Does the original memory trace remain intact and accessible when needed, or is it permanently altered, rendering the original version inaccessible? Research on false memories indicates that suggested memories are temporally unstable and that suggestive influences through exposure to misinformation can be actively reversed (Huffmann et al., 1997; Oeberst & Blank, 2012; Oeberst et al., 2021). These findings support the notion that factual event memory may remain accessible even after it has been altered by misinformation. However, the mechanisms through which psychological treatments modify traumatic memories remain unclear.

Two competing theoretical accounts are particularly relevant: The Retrieval Competition Account proposes that successful treatment results in the formation of a new, adaptive, and less distressing memory trace. The original memory remains intact, but is accessed less frequently due to competition with the new memory trace during retrieval (Brewin, 2006; Brewin et al., 2010). In contrast, it has also been proposed that trauma-focused interventions may directly alter the meaning and emotional valence of the original memory through reconsolidation processes, rendering the memory inaccessible in its original form (e.g., Arntz, 2012; van den Hout & Engelhard, 2012). While the creation of a new, inhibitory memory representation has been proposed to be a shared mechanism of IE and ImRs (Brewin et al., 2010), it has also been suggested that ImRs and EMDR might directly modify the original traumatic memory, which is subsequently reconsolidated in its altered form (Arntz & Weertman, 1999; Arntz, 2012; Dibbets et al., 2018; van den Hout & Engelhard, 2012). Emerging evidence supports the notion that ImRs and EMDR may operate through mechanisms distinct from IE, potentially tackling reconsolidation processes (Dibbets et al., 2012; Jellestad et al., 2021; Kunze et al., 2019; Woelk et al., 2024). However, our studies were not designed to directly investigate these underlying mechanisms, leaving this question open for future research.

Existing evidence suggests that interventions targeting memory reconsolidation, whether pharmacological (Kindt & Soeter, 2018; Sevenster et al., 2013) or behavioral (Golkar et al., 2017; James et al., 2015), selectively affect the emotional components of memory while preserving the declarative recall of factual details. This provides some reassurance regarding the accessibility of factual event details following treatment. However, the extent to which established psychological interventions maintain unrestricted access to all original memory details remains unclear. Therefore, further research into the mechanisms underlying memory modification is crucial to ensure that therapeutic interventions optimize outcomes without compromising the accessibility of relevant memory content.

Practical Implications

Our findings hold important practical implications. Based on concerns that factual memory contents may be distorted through trauma-focused interventions, trauma survivors who consider to pursue legal actions against their perpetrators are often advised to delay psychological treatment until the legal proceedings are concluded (Bublitz et al., 2020). This places them in a difficult position, forcing them to choose between prioritizing their mental health and maintaining credibility in court (Ganslmeier et al., 2022). Reassuringly, our findings question the assumption that trauma-focused interventions inherently impair memory accuracy. However, these findings are not exhaustive and do not rule out the possibility that such interventions could pose risks under conditions not examined in this thesis.

It is critical to consider that the present thesis investigated the effects of trauma-focused interventions under the assumption that these interventions are conducted in accordance with best practices. However, psychological treatment may become a setting that inadvertently fosters false memories when therapists deviate from evidence-based guidelines. Alarmingly, recent research shows that a non-negligible proportion of therapists fail to adhere to best practices, sometimes employing controversial techniques to recover “repressed memories” of trauma (Schemmel et al., 2024; Zapallà et al., 2023) and that a substantial number of EMDR practitioners beliefs in the controversial idea of repressed memories (Houben et al., 2021). Such approaches are likely to significantly increase the risk of false memory formation, particularly for highly burdened patients searching for explanations for their symptoms as these may try to reconstruct supposedly missing memories (Lynn et al., 2015; Schemmel et al., 2024). Ongoing professional education and active efforts to discourage problematic practices are essential to mitigate the risk of suggestive influences in clinical settings.

5.3 General strengths and limitations

This thesis offers several key contributions that advance our understanding of the effects of trauma-focused interventions on memory. First, by systematically examining intervention effects on both voluntary and involuntary memory aspects, the thesis extends prior research, which has typically studied these dimensions in isolation. This integrative approach allowed for the testing of conflicting hypotheses regarding both the intended and unintended memory effects of trauma-focused interventions. Second, a key strength of this thesis lies in its systematic approach to examining potential unintended intervention effects on factual memory content. Studies I and II focused on experimentally induced memories, enabling high control over memory content and assessments of intervention effects on memory accuracy under standardized and replicable conditions. This approach laid an important foundation for Study III, which expanded the investigation to autobiographical memories, thereby taking a critical step toward bridging the gap between experimental paradigms and clinical practice. Third, Study II introduced an innovative approach to experimentally model and evaluate potential risk conditions under which ImRs might impair factual memory content in clinical practice. This is a critical addition to the literature, as such risks have been largely overlooked in prior research. Fourth, unlike previous studies that predominantly relied on simplified stimuli such as word lists, photographs, or film clips, this thesis examined intervention effects on complex, emotionally salient, and personally relevant memories, which are typically the target in clinical treatment. Fifth, the studies in this thesis employed multiple-day paradigms to assess intervention effects on fully consolidated memories, extending previous research that predominantly evaluated effects of interventions which were conducted shortly after memory induction - before memory consolidation could take place (e.g., Hagenaars & Arntz, 2012; Houben et al., 2020). Finally, the large sample sizes across the studies allowed us to detect even small effects on memory accuracy, providing a robust foundation for addressing concerns about potential unintended intervention effects. Collectively, these methodological advancements substantially improve the generalizability of the findings to clinical practice. Nevertheless, several general limitations must be considered when interpreting the results of three studies.

First, an important limitation lies in the relatively short time intervals between memory induction and interventions across all three studies. While this thesis advanced prior research by examining effects on consolidated memories, the intervals were still relatively brief and therefore not fully reflective of clinical practice, where memories are targeted that often date back months or even years. While research suggests that emotional salience and personal relevance play a larger role in memory accuracy than the age of the memory (Goldfarb et al., 2023), older memories may still be more susceptible to distortions as they degrade over time (Johnson et al., 1993). Although Study II sought to address this by experimentally modeling weaker memories, future research should extend these investigations to older memories retained over significantly longer periods to better mirror the conditions of clinical practice.

Second, the studies exclusively included healthy participants, which limits generalizability to clinical populations. Individuals with PTSD, for instance, may show heightened susceptibility to false memories (Otgaar et al., 2017), though findings on this have been mixed (e.g., Moradi et al., 2015; Dasse et al., 2015). This is particularly relevant as PTSD often co-occurs with disorders like substance use (Mills et al., 2006), insomnia (Ohayon et al., 2000), and depression (Walter et al., 2018), all of which have been associated with cognitive impairments (e.g., Fortier-Brochu & Morin, 2014; Morin et al., 2019; Pitel et al., 2007; Schmidt et al., 2010) and/or increased susceptibility to memory distortions (e.g., Brennen et al., 2007; Lövdén, 2003; Malloggi et al., 2022). Additionally, dissociation tendencies (Porter et al., 2008) and subjective memory lapses (Loftus, 2005) may further increase the risk of memory errors. To address these aspects, future research should replicate findings in clinical populations.

Third, the exclusive focus on young adult samples limits the scope of the findings. Expanding the investigation to more diverse age groups could yield important insights. For instance, elderly individuals (Karpel et al., 2001; Davis & Loftus, 2005) and young children

(Ceci & Bruck, 1993) were found to be more susceptible to misinformation than older children and adults. This may be particularly relevant with regard to forensic contexts involving child abuse allegations, where it is essential to ensure that trauma-focused treatment does not compromise memory accuracy and thus avoid undue influence of treatment history on credibility assessments.

Finally, all three studies included in this thesis examined the effects of a single intervention session, whereas clinical practice typically involves multiple sessions (e.g., Matthijssen et al., 2020; Morina et al., 2017; van Minnen & Foa, 2006). Importantly, research indicates that repeated exposure to counterfactual content or misinformation increases the likelihood of memory errors (e.g., Foster et al., 2012). However, repeated elaboration on memory contents may also have a protective effect, given that repeated retrieval of memory details has been shown to improve consistency of memory recall (Nadel et al., 2007). To better align with clinical practice, future studies should investigate how repeated sessions influence memory accuracy, taking into account both the potential risks of misinformation and the benefits of enhanced memory retrieval.

5.4 Conclusion

To conclude, this thesis aimed to advance our understanding of the differential effects of three established trauma-focused interventions - EMDR, ImRs, and IE - on the involuntary and voluntary retrieval of distressing memories. A particular emphasis was placed on systematically examining potential unintended effects of these interventions on the factual content of memories targeted during treatment. Three experimental studies conducted with healthy participants provided the empirical basis for this investigation. In summary, the findings challenge concerns that trauma-focused interventions inherently risk distorting factual memory contents. Specifically, no adverse effects were observed on the accuracy of experimentally induced memories, and no increase in contradictions or omissions was found in memory reports of autobiographical memories. However, the observed increase in additions to memory reports following IE warrants cautious interpretation, as it remains unclear whether these added details reflect accurate or inaccurate event information. Future research is needed to better understand how memory details evolve throughout treatment, particularly in clinical populations and for real traumatic memories. Additionally, the mixed findings regarding intervention effects on involuntary memories, as well as the disorganization and coherence of voluntary memories, highlights that refining both theoretical models and research methodologies will be crucial to further disentangle the complex memory effects of trauma-focused interventions. Such efforts are crucial to ensure that, after treatment, remembering (again) serves its adaptive purpose - allowing individuals to reconcile with their past, while fostering a coherent and meaningful understanding of their experiences. In doing so, we can help individuals avoid the fate of Borges' Funes, whose uncontrolled and overwhelming memory ultimately rendered him incapable of truly living.

6 Deutsche Zusammenfassung

Die Differentiellen Effekte Traumafokussierter Interventionen auf den willentlichen und unwillentlichen Abruf belastender Erinnerungen: Einblicke aus Analogstudien

Die posttraumatische Belastungsstörung (PTBS) gehört zu den häufigsten Traumafolgestörungen (American Psychiatric Association [APA], 1994). Sie ist durch belastende emotionale Erinnerungen an das traumatische Ereignis gekennzeichnet und wird daher als Gedächtnisstörung konzeptualisiert (z.B. Visser et al., 2018). Konkret manifestieren sich Störungen des Gedächtnisses in zwei Symptomclustern, die in der fünften Ausgabe des *Diagnostic and Statistical Manual of Mental Disorders* (DSM-5; APA, 2013, S. 217–272) beschrieben werden: dem persistierenden Wiedererleben des traumatischen Ereignisses in Form von intrusiven Erinnerungen, Flashbacks und Alpträumen, begleitet von erhöhten psychologischen und physiologischen Reaktionen auf traumaassoziierte Reize, sowie Schwierigkeiten beim willentlichen Abruf spezifischer Details des traumatischen Ereignisses.

Mehrere klinische Theorien betonen die zentrale Rolle von Gedächtnisstörungen bei der Entstehung und Aufrechterhaltung der PTBS (Brewin et al., 1996; 2010; Foa & Kozak, 1986; Ehlers & Clark, 2000). Unter diesen Theorien bietet die Dual Representation Theory (DRT; Brewin et al., 1996; 2010) den umfassendsten und mechanistischsten Rahmen, um das gleichzeitige Auftreten von vermehrten unwillkürlichen Erinnerungen einerseits und eingeschränktem willentlichen Abruf andererseits zu erklären. Die DRT geht davon aus, dass traumatische Erfahrungen zwei Arten von Gedächtnisrepräsentationen bilden: (a) vorwiegend sensorische Repräsentationen (S-reps) und (b) kontextualisierte Repräsentationen (C-reps). S-reps speichern detaillierte sensorische und emotionale Aspekte des traumatischen Ereignisses und sind eng mit den körperlichen und emotionalen Reaktionen verknüpft, die während des Traumas erlebt wurden. Diese Repräsentationen werden automatisch getriggert und sind nicht für den willkürlichen Abruf zugänglich. Im Gegensatz dazu umfassen C-reps komplexere und abstraktere Gedächtnisrepräsentationen, die kontextuelle und semantische Informationen enthalten, wie Zeit, Ort und Bedeutung des traumatischen Ereignisses. C-reps können zwar ebenfalls automatisch getriggert werden, sind jedoch ,im Gegensatz zu S-reps, auch willentlich abrufbar. Bei gesunden Personen führt die Enkodierung einer traumatischen Erinnerung zur

Bildung von S-reps, C-reps sowie von Assoziationen zwischen S-reps und C-reps. Diese Verknüpfung ermöglicht es, dass S-reps zusammen mit den entsprechenden C-reps abgerufen werden. Dies unterstützt die Kontextualisierung von Erinnerungselementen sowie die inhibitorische Kontrolle des unwillkürlichen Abrufs von S-reps. Bei Menschen mit PTBS führt jedoch extremer Stress während des Traumas zu einer Störung des Enkodierungsprozesses. Dabei wird die Bildung von S-reps verstärkt, während die Bildung von C-reps sowie die Verknüpfung zwischen S-reps und C-reps beeinträchtigt wird. Infolgedessen sind die Traumaerinnerungen der Betroffenen wenig elaboriert und kontextualisiert. Dies äußert sich einerseits in einem inkohärenten und desorganisierten willkürlichen Erinnerungsabruf und andererseits in vermehrten intrusiven Erinnerungen, die durch die Aktivierung von S-reps ausgelöst werden (Brewin, 2014; Brewin et al., 2010).

In der Behandlung der PTBS haben sich Interventionen, die direkt an der Verarbeitung der Traumaerinnerung ansetzen, als besonders wirksam erwiesen (Bisson et al., 2007) und werden von internationalen Behandlungsleitlinien als Behandlung erster Wahl empfohlen (APA, 2017; Schäfer et al., 2019). Zu diesen sogenannten traumafokussierten Interventionen zählen die traumafokussierte kognitive Verhaltenstherapie, die typischerweise prolongierte imaginative Exposition (IE) enthält (Foa & Rothbaum, 1998), sowie Eye Movement Desensitization and Reprocessing (EMDR; Shapiro, 1989; 2018). Darüber hinaus hat sich Imagery Rescripting (ImRs; Arntz & Weertman, 1999) als effektiv in der Behandlung von Traumafolgestörungen erwiesen (z. B. Kip et al., 2023; Morina et al., 2017), wurde jedoch bislang noch nicht in die Empfehlungen der Leitlinien aufgenommen.

Bei der IE (Foa et al., 1999) durchleben die Patienten ihre traumatische Erinnerung wiederholt in der Vorstellung, bis die emotionale Belastung nachlässt. EMDR (Shapiro, 2001) kombiniert den Erinnerungsabruf mit horizontalen Augenbewegungen oder anderen Formen bilateraler Stimulation. Im Rahmen von ImRs (Arntz & Weertman, 1999) reaktivieren die Patienten ihre traumatische Erinnerung in der Imagination und verändern anschließend den

Verlauf der Ereignisse so, dass diese als weniger belastend erlebt werden. Beispielsweise könnte in der Imagination eine helfende Figur in die Szene treten, den Täter konfrontieren und sich um das Opfer kümmern (Arntz & Weertman, 1999).

Obwohl lebhafte Erinnerungen an das Trauma häufig als eines der belastendsten Symptome von Betroffenen beschrieben werden (Ehlers et al., 2004; Holmes & Mathews, 2010), ist das Ziel traumafokussierter Interventionen nicht, diese Erinnerungen vollständig auszulöschen. In vielen Situationen ist das willkürliche Erinnern eines traumatischen Ereignisses notwendig oder sogar essenziell. Beispielsweise muss eine Polizeibeamtin in der Lage sein, sich an Details eines vergangenen Einsatzes zu erinnern, um zukünftige Risikosituationen besser einschätzen zu können. Ein Überlebender eines tätlichen Angriffs könnte auf den akkuraten Erinnerungsabruf angewiesen sein, um rechtliche Schritte gegen den Täter einzuleiten. Traumafokussierte Behandlungen zielen daher darauf ab, den unwillkürlichen Abruf von Traumaerinnerungen gezielt und selektiv zu reduzieren, während der kontrollierte, willkürliche Abruf erhalten oder sogar gefördert werden soll.

Laut der Dual Representation Theory fördern traumafokussierte Interventionen wie IE, EMDR und ImRs die Integration der bei PTBS dissoziierten Gedächtnisrepräsentationen (S-reps und C-reps). Dies soll den willentlichen Zugriff auf traumatische Erinnerungen erleichtern und dadurch die Kohärenz sowie Organisation der Erinnerungen verbessern. Gleichzeitig wird angenommen, dass die inhibitorische Kontrolle über den unwillkürlichen Abruf gestärkt wird, was zu einer Reduktion intrusiver Erinnerungen führt (Brewin, 2014; Brewin et al., 2010).

Empirische Studien konnten diese theoretischen Annahmen bisher jedoch nur teilweise bestätigen. Während die Wirksamkeit traumafokussierter Interventionen bei der Reduktion intrusiver Erinnerungen gut belegt ist (Cusack et al., 2016; Ehring et al., 2004; Wright et al., 2024), zeigt sich hinsichtlich der Effekte auf die willentliche Erinnerung ein uneinheitliches Bild. Für IE gibt es bislang keine konsistente Evidenz, dass diese Intervention die Organisation und Kohärenz willentlicher Erinnerungen verbessert (Bedard-Gilligan et al., 2017; Foa et al., 1995; Van Minnen et al., 2002). Zudem fehlen weitgehend Hinweise darauf, dass die Reorganisation von Erinnerungen ein zentraler Wirkmechanismus von IE ist (Cooper et al., 2017). Für EMDR und ImRs gibt es zwar Anhaltspunkte, dass sie die emotionale Valenz (Rameckers et al., 2024) sowie die Intensität und Lebendigkeit (Houben et al., 2020; Lee & Kwon, 2013) aversiver Erinnerungen verringern können. Ob diese Veränderungen jedoch mit einer verbesserten Organisation und Kohärenz der Erinnerungen einhergehen, wie von der DRT vorhergesagt, bleibt unklar (Arntz et al., 2007; Meckling et al., 2024).

Im Gegensatz zu den Annahmen klinischer Theorien, äußern Experten aus der Aussagepsychologie anhaltend Bedenken, dass traumafokussierte Interventionen den willentlichen Gedächtnisabruf nicht verbessern, sondern im Gegenteil diesen sogar beeinträchtigen könnten (e.g., Otgaar et al., 2021). Besonders kritisch wird hierbei die Möglichkeit betrachtet, dass faktische Gedächtnisinhalte durch die Interventionen verändert oder verzerrt werden könnten. Diese Befürchtung stützt sich auf experimentelle Studien, die zeigten, dass Erinnerungen fehleranfällig sind und durch Imagination („Imagination Inflation Effect“, Garry et al., 1996) sowie durch die Exposition gegenüber kontrafaktischen Informationen („Misinformation Effect“, Goff & Roediger, 1998) verändert werden können. Da ImRs, EMDR und IE imaginative Techniken beinhalten und ImRs sogar die aktive Veränderung von Ereignisabläufen in der Vorstellung vorsieht, stehen diese Interventionen besonders im Fokus der Kritik.

Entgegen dieser Bedenken deuten bisherige Studien jedoch darauf hin, dass weder IE noch ImRs faktische Gedächtnisinhalte beeinträchtigen (Ganslmeier et al., 2022, 2023; Hagenaars & Arntz, 2012). Für EMDR hingegen sind die Befunde weniger eindeutig: Während in einigen Studien beobachtet wurde, dass Augenbewegungen, die während des Erinnerungsabrufs durchgeführt werden, zu einer Verzerrung faktischer Gedächtnisinhalte führen (Houben et al., 2018; Leer & Engelhard, 2020), konnten andere Studien diese Ergebnisse nicht replizieren (z.B. Calvillo & Emami, 2019; Schie & Leer, 2019). Insgesamt ist jedoch festzustellen, dass die Aussagekraft bisheriger Studien in vielerlei Hinsicht eingeschränkt ist. Viele Untersuchungen verwendeten stark vereinfachte Interventionsprotokolle (e.g., Calvillo & Emami, 2019; Houben et al., 2018, 2020) und führten die Intervention unmittelbar nach der Erinnerungsinduktion durch (z. B. Hagenaars & Arntz, 2012; Houben et al., 2018, 2020), also bevor eine Konsolidierung der Erinnerung stattfinden konnte (Stickgold, 2005). Zudem wurden oft einfache Erinnerungen an Wortlisten (e.g., Houben et al., 2020), Videoclips (e.g., Calvillo & Emami, 2019; Ganslmeier et al., 2023; Houben et al., 2018) oder Bilder (e.g., Leer et al., 2017; Leer & Engelhard, 2020) untersucht, die weder in ihrer Komplexität noch in ihrer emotionalen Intensität mit traumatischen Erinnerungen vergleichbar sind.

Zusammenfassend bleibt also unklar, ob traumafokussierte Interventionen wie EMDR, ImRs und IE tatsächlich wie beabsichtigt unwillkürliche Erinnerungen selektiv reduzieren und gleichzeitig den willentlichen Abruf bewahren oder sogar verbessern können. Während die Wirksamkeit dieser Interventionen bei der Reduktion unwillkürlicher Erinnerungen gut belegt ist, wurden ihre Effekte auf den willentlichen Erinnerungsabruf bisher unzureichend erforscht. Erste vorläufige Studien deuten darauf hin, dass EMDR, IE und ImRs möglicherweise zu Unrecht verdächtigt werden, die faktische Richtigkeit willentlicher Erinnerungen zu beeinträchtigen. Aufgrund methodischer Limitationen erlauben die bisherigen Befunde jedoch keine endgültigen Schlussfolgerungen. Darüber hinaus bleibt unklar, ob und wie diese Interventionen die Qualität willentlicher Erinnerungen – insbesondere in Bezug auf Kohärenz und Desorganisation – beeinflussen und ob sich ihre Effekte unterscheiden. Das vorliegende Projekt hatte daher zum Ziel, das Verständnis für die differentiellen Effekte traumafokussierter Interventionen auf den willentlichen und unwillentlichen Erinnerungsabruf zu verbessern. Zu diesem Zweck wurden die Effekte von IE, EMDR und ImRs in drei experimentellen Analogstudien an gesunden Stichproben untersucht.

Studie I und *II* untersuchten die Effekte dieser Interventionen auf experimentell induzierte Erinnerungen, wodurch eine hohe experimentelle Kontrolle über Gedächtnisinhalte und damit eine Beurteilung der Richtigkeit der Erinnerung ermöglicht wurde. In *Studie I* wurde bei *N* = 265 Teilnehmenden eine belastende Erinnerung durch den Trier Social Stress Test (TSST) induziert. Am folgenden Tag erhielten die Teilnehmenden entweder IE, EMDR, ImRs oder keine Intervention (NIC). Eine Woche später wurde die faktische Richtigkeit der willentlichen Erinnerung an den TSST mittels einer Cued-Recall-Aufgabe untersucht. Unwillentliche Erinnerungen an den TSST wurden mit einem App-basierten Intrusionstagebuch erfasst. Die Ergebnisse zeigten, dass es keine Gruppenunterschiede in der Richtigkeit der willentlichen Erinnerung gab. Die Interventionen führten weder zu einer Beeinträchtigung noch zu einer Verbesserung der faktischen Gedächtnisinhalte. Bezüglich der unwillentlichen Erinnerung zeigte sich, dass keine der Interventionen die Häufigkeit von Intrusionen signifikant reduzierte. Allerdings waren EMDR und IE mit einer Verringerung des Intrusion Load (Häufigkeit der Intrusionen gewichtet nach Belastungsintensität) verbunden. Obwohl das Ausbleiben von Beeinträchtigungen der faktischen Erinnerung ist aus klinischer Sicht ermutigend ist, schließt dies jedoch nicht aus, dass bestimmte Bedingungen in der klinischen Anwendung dieser Interventionen das Risiko von Gedächtnisverzerrungen erhöhen könnten.

Studie II hatte daher zum Ziel, spezifische Risikobedingungen zu untersuchen, unter denen ImRs zu Gedächtnisverzerrungen führen könnte. Dabei wurde untersucht, ob die Instruktion, Veränderungen der Erinnerung im Rescripting möglichst lebhaft und detailliert zu imaginieren, das Risiko für Gedächtnisverzerrungen erhöht und ob unklare oder unvollständige Erinnerungen hierfür besonders anfällig sind. In einem dreitägigen Online-Traumafilm-Paradigma wurde bei *N* = 267 Teilnehmenden eine belastende Erinnerung durch einen aversiven Filmausschnitt induziert. Um die Vollständigkeit und Klarheit der Erinnerung zu manipulieren, wurde den Teilnehmenden entweder die Originalversion des Films präsentiert, in der alle sensorischen Informationen klar erkennbar waren, oder eine Version, in der visuelle und auditive Unschärfefilter Teile des Bildes und der Dialoge unkenntlich machten, Am darauffolgenden Tag wurden die Teilnehmenden zufällig einer von drei Bedingungen zugeteilt: ImRs mit Instruktionen, sich die Szene so lebendig wie möglich und mit möglichst vielen sensorischen Details vorzustellen und in der Imagination umzuschreiben; ImRs ohne solche Instruktionen; oder einer Kontrollbedingung ohne Intervention (NIC). Am dritten Tag wurde die Richtigkeit der Erinnerung an den Filmausschnitt mittels einer Cued-Recall-Aufgabe erfasst. Intrusive Erinnerungen an den Filmausschnitt wurden mithilfe eines retrospektiven Intrusionstagebuchs erfasst. Die Ergebnisse zeigten, dass ImRs keine negativen Auswirkungen auf die Richtigkeit der Erinnerung hatte. Im Gegenteil: Teilnehmende, die im Rahmen von ImRs detaillierte sensorische Instruktionen erhielten, zeigten eine bessere Erinnerungsleistung als diejenigen, die ImRs ohne solche Instruktionen durchführten, und als die Kontrollgruppe. Dieser Effekt war unabhängig von der Klarheit und Vollständigkeit der Ursprungserinnerung. Hinsichtlich der Häufigkeit intrusiver Erinnerungen wurden keine signifikanten Gruppenunterschiede festgestellt.

Aufbauend auf diesen Ergebnissen wurde in *Studie III* die Untersuchung auf autobiografische Erinnerungen ausgeweitet. Insgesamt berichteten N = 182 Teilnehmende in einer Free-Recall-Aufgabe detailliert über ein belastendes Lebensereignis. Anschließend wurden sie zufällig einer von vier Bedingungen zugewiesen: IE, EMDR, ImRs oder NIC. Eine Woche später wiederholten die Teilnehmenden die Free-Recall-Aufgabe. Unabhängige Rater bewerteten Veränderungen in der Konsistenz, Desorganisation und Kohärenz der willentlichen Erinnerung. Unwillkürliche Erinnerungen an das Ereignis wurden vor und nach der Intervention mit einem appbasierten Intrusionstagebuch erfasst. Zusätzlich wurde in beiden experimentellen Sitzungen die psychophysiologische Reaktivität auf Intrusionen während einer Intrusions-Sampling-Periode gemessen. Die Ergebnisse zeigten, dass keine der Interventionen im Vergleich zur Kontrollgruppe zu mehr Widersprüchen oder Auslassungen im Free-Recall führte. Dies deutet darauf hin, dass die Interventionen weder die Fähigkeit beeinträchtigen, spezifische Gedächtnisinhalte abzurufen, noch deren Inhalt verzerrten. Allerdings führte IE im

Vergleich zur Kontrollgruppe zu mehr Ergänzungen im Free-Recall. Die Richtigkeit dieser Ergänzungen bleibt jedoch unklar. Hinsichtlich der Desorganisation und Kohärenz der willentlichen Erinnerungen zeigten sich gemischte Ergebnisse. IE reduzierte desorganisierte Gedanken, was auf eine Verbesserung der strukturellen Organisation der Erinnerungen hinweist. EMDR und ImRs verbesserten hingegen die kontextuelle Kohärenz, die sich in einer besseren räumlichen und zeitlichen Orientierung der Erinnerungsberichte widerspiegelte. Bzeüglich der unwillentlichen Erinnerung zeigte sich, dass alle Interventionen effektiv den Intrusion Load reduzierten. Bezüglich der psychophysiologischen Reaktionen auf intrusive Erinnerungen wurden jedoch keine Gruppenunterschiede festgestellt.

Zusammenfassend leistet die vorliegende Arbeit einen wichtigen Beitrag zum aktuellen Forschungsstand, indem sie widersprüchliche Annahmen zu den Gedächtniseffekten traumafokussierter Interventionen systematisch untersuchte. Die Ergebnisse entkräften die Befürchtung, dass diese Interventionen grundsätzlich das Risiko einer Verzerrung von faktischen Gedächtnisinhalten bergen. Dies hat wichtige Implikationen für die Arbeit mit Traumaüberlebenden, denen im Kontext eines bevorstehenden Gerichtsprozesses oft vom Beginn einer Psychotherapie vor Abschluss der Beweisaufnahme abgeraten wird – aus Sorge, dass eine traumafokussierte Therapie in der Vorgeschichte ihrer Glaubwürdigkeit vor Gericht schaden könnte. Die in dieser Arbeit vorgestellten Studien liefern wichtige neue Erkenntnisse, da sie im Vergleich zu früheren Forschungsarbeiten die spezifischen Eigenschaften von Erinnerungen, die typischerweise in der klinischen Praxis behandelt werden, stärker berücksichtigten (Studien I und II) und die ökologische Validität durch die Untersuchung autobiografischer Erinnerungen erhöhten (Studie III). Dennoch bleibt die Übertragbarkeit der Ergebnisse auf traumatische Erinnerungen und klinische Populationen begrenzt. Eine Replikation der Befunde in klinischen Stichproben und mit realen traumatischen Erinnerungen ist daher unerlässlich. Zudem verdeutlichen die gemischten Befunde zu intrusiven Erinnerungen und zur Kohärenz und Desorganisation willentlicher Erinnerungen die

Notwendigkeit, experimentelle Paradigmen und theoretische Modelle weiterzuentwickeln, um die differenzierten Effekte traumafokussierter Interventionen präziser zu erfassen. Die vorliegende Arbeit erweitert damit nicht nur unser Verständnis der Gedächtniseffekte etablierter traumafokussierter Interventionen, sondern zeigt auch entscheidende Ansatzpunkte für zukünftige Forschungsarbeiten auf.

References

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Arlington, VA: American Psychiatric Publishing.

American Psychological Association. (2017). Clinical practice guideline for the treatment of posttraumatic stress disorder (PTSD) in adults.

Anderson, A. K., Yamaguchi, Y., Grabski, W., & Lacka, D. (2006). Emotional memories are not all created equal: Evidence for selective memory enhancement. *Learning and Memory*, *13*(6), 711–718. https://doi.org/10.1101/lm.388906

Anderson, M. C., Bjork, R. A., & Bjork, E. L. (1994). Remembering Can Cause Forgetting: Retrieval Dynamics in Long-Term Memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *20*(5), 1063–1087. https://doi.org/10.1037/0278-7393.20.5.1063

Arntz, A., & Weertman, A. (1999). *Treatment of childhood memories : theory and practice*. *37*, 715–740.

Arntz, A., Tiesema, M., & Kindt, M. (2007). Treatment of PTSD: A comparison of imaginal exposure with and without imagery rescripting. *Journal of behavior therapy and experimental psychiatry, 38*(4), 345-370.

Arntz, A., & Weertman, A. (2007). The influence of comorbid personality disorders on the outcome of CBT treatment of anxiety disorders. *European Psychiatry, 22*(1), 16-17

Arntz, A. (2012). Imagery Rescripting as a Therapeutic Technique: Review of Clinical Trials, Basic Studies, and Research Agenda. *Journal of Experimental Psychopathology*, *3*(2), 189–208. https://doi.org/10.5127/jep.024211

Arntz, A., Thoma, T., & McKay, D. (2014). Imagery rescripting for posttraumatic stress disorder. In N. Thoma & D. McKay (Eds.), *Working with emotion in cognitive-behavioral therapy: Techniques for clinical practice* (pp. 203–215). The Guilford Press.

Bedard-Gilligan, M., Zoellner, L. A., & Feeny, N. C. (2017). Is Trauma Memory Special? Trauma Narrative Fragmentation in PTSD: Effects of Treatment and Response. *Clinical Psychological Science*, *5*(2), 212–225. https://doi.org/10.1177/2167702616676581

Berntsen, D., Willert, M., & Rubin, D. C. (2003). Splintered memories or vivid landmarks? Qualities and organization of traumatic memories with and without PTSD. *Applied Cognitive Psychology*, *17*(6), 675–693. https://doi.org/10.1002/acp.894

Birrer, E., Michael, T., & Munsch, S. (2007). Intrusive images in PTSD and in traumatised and non-traumatised depressed patients: A cross-sectional clinical study. *Behaviour Research and Therapy*, *45*(9), 2053–2065. https://doi.org/10.1016/j.brat.2007.03.005

Bisson, J. I., Ehlers, A., Matthews, R., Pilling, S., Richards, D., & Turner, S. (2007). Psychological treatments for chronic post-traumatic stress disorder: Systematic review and meta-analysis. *British Journal of Psychiatry*, *190*(FEB.), 97–104. https://doi.org/10.1192/bjp.bp.106.021402

Bisson JI, Berliner L, Cloitre M, Forbes D, Jensen TK, Lewis C, Monson CM, Olff M, Pilling S, Riggs DS, Roberts NP, Shapiro F. (2019). The International Society for Traumatic Stress Studies New Guidelines for the Prevention and Treatment of PTSD: Methodology and Development Process. *Journal of Traumatic Stress*, 32, 475-483.

Blank, H., & Launay, C. (2014). How to protect eyewitness memory against the misinformation effect: A meta-analysis of post-warning studies. *Journal of Applied Research in Memory and Cognition*, *3*(2), 77–88. https://doi.org/10.1016/j.jarmac.2014.03.005

Boterhoven De Haan, K. L., Lee, C. W., Fassbinder, E., Van Es, S. M., Menninga, S., Meewisse, M. L., Rijkeboer, M., Kousemaker, M., & Arntz, A. (2020). Imagery rescripting and eye movement desensitisation and reprocessing as treatment for adults with post-traumatic stress disorder from childhood trauma: Randomised clinical trial. *British Journal of Psychiatry*, *217*(5), 609–615. https://doi.org/10.1192/bjp.2020.158

Brainerd, C. J., & Reyna, V. F. (2002). Fuzzy-trace theory and false memory. *Current Directions in Psychological Science*, *11*(5), 164–169. https://doi.org/10.1111/1467-8721.00192

Brennen, T., Dybdahl, R., & Kapidžić, A. (2007). Trauma-related and neutral false memories in war-induced Posttraumatic Stress Disorder. *Consciousness and Cognition*, *16*(4), 877–885. https://doi.org/10.1016/j.concog.2006.06.012

Brewin, C. R. (2001). A cognitive neuroscience account of posttraumatic stress disorder and its treatment. *Behaviour Research and Therapy*, *39*(4), 373–393. https://doi.org/10.1016/S0005-7967(00)00087-5

Brewin, C. R. (2006). Understanding cognitive behaviour therapy: A retrieval competition account. *Behaviour Research and Therapy*, *44*(6), 765–784. https://doi.org/10.1016/j.brat.2006.02.005

Brewin, C. R. (2015). Re-experiencing traumatic events in PTSD: New avenues in research on intrusive memories and flashbacks. *European Journal of Psychotraumatology*, *6*. https://doi.org/10.3402/ejpt.v6.27180

Brewin, C. R., & Andrews, B. (2017a). Creating Memories for False Autobiographical Events in Childhood: A Systematic Review. *Applied Cognitive Psychology*, *31*(1), 2–23. https://doi.org/10.1002/acp.3220

Brewin, C. R., & Andrews, B. (2017b). Creating Memories for False Autobiographical Events in Childhood: A Systematic Review. *Applied Cognitive Psychology*, *31*(1), 2–23. https://doi.org/10.1002/acp.3220

Brewin, C. R., & Burgess, N. (2014). Contextualisation in the revised dual representation theory of PTSD: A response to Pearson and colleagues. *Journal of Behavior Therapy and Experimental Psychiatry*, *45*(1), 217–219. https://doi.org/10.1016/j.jbtep.2013.07.011

Brewin, C. R., Dalgleish, T., & Joseph, S. (1996). A dual representation theory of Posttraumatic Stress Disorder. *Psychological Review*, *103*(4), 670–686.

Brewin, C. R., & Field, A. P. (2024). Meta-Analysis Shows Trauma Memories in Posttraumatic Stress Disorder Lack Coherence: A Response to Taylor et al. (2022). *Clinical Psychological Science*, *2022*. https://doi.org/10.1177/21677026241240456

Brewin, C. R., Gregory, J. D., Lipton, M., & Burgess, N. (2010). Intrusive Images in Psychological Disorders: Characteristics, Neural Mechanisms, and Treatment Implications. *Psychological Review*, *117*(1), 210–232. https://doi.org/10.1037/a0018113

Brewin, C. R., Wheatley, J., Patel, T., Fearon, P., Hackmann, A., Wells, A., Fisher, P., & Myers, S. (2009). Imagery rescripting as a brief stand-alone treatment for depressed patients with intrusive memories. *Behaviour Research and Therapy, 47*(7), 569–576. https://doi.org/10.1016/j.brat.2009.03.008

Bryant, R. A., Creamer, M., O'Donnell, M., Forbes, D., McFarlane, A. C., Silove, D., & Hadzi-Pavlovic, D. (2017). Acute and chronic posttraumatic stress symptoms in the emergence of posttraumatic stress disorder a network analysis. *JAMA Psychiatry*, *74*(2), 135–142. https://doi.org/10.1001/jamapsychiatry.2016.3470

Bryant, R. A., O'Donnell, M. L., Creamer, M., McFarlane, A. C., & Silove, D. (2011). Posttraumatic intrusive symptoms across psychiatric disorders. *Journal of Psychiatric Research, 45*(6), 842–847. https://doi.org/10.1016/j.jpsychires.2010.11.012

Bublitz, C. (2020). Health or credibility? Overcoming the dilemma of trauma therapy. *Ethik in der Medizin, 32,* 65-83.

Calvillo, D. P., & Emami, A. S. (2019). Do lateral eye movements increase susceptibility to misinformation? A registered replication. *Psychonomic bulletin & review, 26,* 1905-1910.

Cann, D. R., McRae, K., & Katz, A. N. (2011). False Recall in the Deese–Roediger–McDermott Paradigm: The Roles of Gist and Associative Strength. *Quarterly Journal of Experimental Psychology, 64*(8), 1515-1542.

Ceci, S. J., & Bruck, M. (1993). Suggestibility of the child witness: A historical review and synthesis. *Psychological Bulletin, 113*(3), 403–439. https://doi.org/10.1037/0033-2909.113.3.403

Constantino, M. J., Visla, A., Coyne, A. E., & Boswell, J. F. (2018). A Meta-Analysis of the Association between Patients' Early Treatment Outcome Expectation and Their Posttreatment Outcomes. *Psychotherapy*, *55*(4), 473–485. https://doi.org/10.1037/pst0000169

Cooper, A. A., Clifton, E. G., & Feeny, N. C. (2017). An Empirical Review of Potential Mediators and Mechanisms of Prolonged Exposure Therapy. *Clinical Psychology Review*, *56,* 106–121. https://doi.org/doi:10.1016/j.cpr.2017.07.003

Craske, M. G., Treanor, M., Conway, C. C., Zbozinek, T., & Vervliet, B. (2014). Maximizing exposure therapy: An inhibitory learning approach. *Behaviour Research and Therapy, 58*, 10–23. https://doi.org/10.1016/j.brat.2014.04.006

Cuijpers, P., Noma, H., Karyotaki, E., Vinkers, C. H., Cipriani, Andrea, & Furukawa, T. A. (2020). A network meta-analysis of the effects of psychotherapies, pharmacotherapies and their combination in the treatment of adult depression. *World Psychiatry, 19*(1), 92–107. https://doi.org/10.1002/wps.20701

Cusack, K., Jonas, D. E., Forneris, C. A., Wines, C., Sonis, J., Middleton, J. C., ... & Gaynes, B. N. (2016). Psychological treatments for adults with posttraumatic stress disorder: A systematic review and meta-analysis. *Clinical psychology review, 43,* 128-141.

Dasse, M. N., Juback, S. K., Morissette, S. B., Dolan, S. L., & Weaver, C. A. (2015). False memory susceptibility in OEF/OIF veterans with and without PTSD. *Military Psychology, 27*(6), 354–365. https://doi.org/10.1037/mil0000094

Davis, D., & Loftus, E. F. (2005). Age and functioning in the legal system: Victims, witnesses and Jurors. In Y. I. Noy & W. Karwowski (Eds.), *Handbook of human factors in* *litigation* (pp. 11-1 to 11-53). New York: CRC Press.

De Jongh, A., Ernst, R., Marques, L., & Hornsveld, H. (2013). The impact of eye movements and tones on disturbing memories involving PTSD and other mental disorders. *Journal of Behavior Therapy and Experimental Psychiatry*, *44*(4), 477–483. https://doi.org/10.1016/j.jbtep.2013.07.002

Deese, J. (1959). On the prediction of occurrence of particular verbal intrusions in immediate recall. *Journal of experimental psychology*, *58*(1), 17.

de Vries, V., de Jong, A. E. E., Hofland, H. W. C., & Van Loey, N. E. (2021). Pain and Posttraumatic Stress Symptom Clusters: A Cross-Lagged Study. *Frontiers in Psychology*, *12*, 1–8. https://doi.org/10.3389/fpsyg.2021.669231

Deeprose, C., Zhang, S., Dejong, H., Dalgleish, T., & Holmes, E. A. (2012). Imagery in the aftermath of viewing a traumatic film: Using cognitive tasks to modulate the development of involuntary memory. *Journal of Behavior Therapy and Experimental Psychiatry*, *43*(2), 758–764. https://doi.org/10.1016/j.jbtep.2011.10.008

Dibbets, P., & Arntz, A. (2016). Imagery rescripting: Is incorporation of the most aversive scenes necessary? *Memory*, *24*(5), 683–695. https://doi.org/10.1080/09658211.2015.1043307

Dibbets, P., Lemmens, A., & Voncken, M. (2018). Turning negative memories around: Contingency versus devaluation techniques. *Journal of Behavior Therapy and Experimental Psychiatry*, *60*, 5–12. https://doi.org/10.1016/j.jbtep.2018.02.001

Dibbets, P., Poort, H., & Arntz, A. (2012a). Adding imagery rescripting during extinction leads to less ABA renewal. *Journal of Behavior Therapy and Experimental Psychiatry*, *43*(1), 614–624. https://doi.org/10.1016/j.jbtep.2011.08.006

Dibbets, P., Poort, H., & Arntz, A. (2012b). Adding imagery rescripting during extinction leads to less ABA renewal. *Journal of Behavior Therapy and Experimental Psychiatry*, *43*(1), 614–624. https://doi.org/10.1016/j.jbtep.2011.08.006

Dorahy, M. J., & van der Hart, O. (2015). DSM–5's Posttraumatic Stress Disorder with Dissociative Symptoms: Challenges and Future Directions. *Journal of Trauma and Dissociation*, *16*(1), 7–28. https://doi.org/10.1080/15299732.2014.908806

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., Hackmann, A., & Michael, T. (2004a). Intrusive re-experiencing in post-traumatic stress disorder: Phenomenology, theory, and therapy. *Memory*, *12*(4), 403–415. https://doi.org/10.1080/09658210444000025

Ehlers, A., Hackmann, A., & Michael, T. (2004b). Intrusive re-experiencing in post-traumatic stress disorder: Phenomenology, theory, and therapy. *Memory*, *12*(4), 403–415. https://doi.org/10.1080/09658210444000025

Ehlers, A., Hackmann, A., Steil, R., Clohessy, S., Wenninger, K., & Winter, H. (2002). The nature of intrusive memories after trauma: The warning signal hypothesis. *Behaviour Research and Therapy*, *40*(9), 995–1002. https://doi.org/10.1016/S0005-7967(01)00077-8

Ehring, T., Welboren, R., Morina, N., Wicherts, J. M., Freitag, J., & Emmelkamp, P. M. G.

(2014). Meta-analysis of psychological treatments for posttraumatic stress disorder in adult survivors of childhood abuse. *Clinical Psychology Review*, *34*(8), 645–657. https://doi.org/10.1016/j.cpr.2014.10.004

Evans, C., Ehlers, A., Mezey, G., & Clark, D. M. (2007). Intrusive memories in perpetrators of violent crime: Emotions and cognitions. *Journal of Consulting and Clinical Psychology, 75*(1), 134–144. https://doi.org/10.1037/0022-006X.75.1.134

Expertengruppe „Psychotherapie und Glaubhaftigkeit“ im Bundesministerium der Justiz. (2024). *Praxishinweise zum Verhältnis von Psychotherapie und Strafverfahren.* Bundesministerium der Justiz

Foa, E. B., & Kozak, M. J. (1986). Emotional Processing of Fear. Exposure to Corrective Information. *Psychological Bulletin*, *99*(1), 20–35. https://doi.org/10.1037/0033-2909.99.1.20

Foa, E. B., Molnar, C., & Cashman, L. (1995). Change in rape narratives during exposure therapy for posttraumatic stress disorder. *Journal of Traumatic Stress, 8*(4), 675–690. https://doi.org/10.1007/BF02102894

Foa, E. B., & Rothbaum, B. O. (1998). *Treating the trauma of rape: A cognitive-behavioral therapy for PTSD*. New York: Guilford.

Foa, E. B., Steketee, G., & Rothbaum, B. O. (1989). Behavioral/cognitive conceptualizations of post-traumatic stress disorder. *Behavior Therapy*, *20*(2), 155–176. https://doi.org/10.1016/S0005-7894(89)80067-X

Foa, E. B., Huppert, J. D., & Cahill, S. P. (2006). Emotional Processing Theory: An Update. In B. O. Rothbaum (Ed.), Pathological anxiety: *Emotional processing in etiology and treatment* (pp. 3–24). The Guilford Press.

oa, E. B., Hembree, E. A., & Rothbaum, B. O. (2007). *Prolonged exposure therapy for PTSD: Emotional processing of traumatic experiences: Therapist guide.* Oxford University Press.

Fortier-Brochu, É., & Morin, C. M. (2014). Cognitive impairment in individuals with insomnia: Clinical significance and correlates. *Sleep*, *37*(11), 1787–1798. https://doi.org/10.5665/sleep.4172

Foster, J. L., Huthwaite, T., Yesberg, J. A., Garry, M., & Loftus, E. F. (2012). Repetition, not number of sources, increases both susceptibility to misinformation and confidence in the accuracy of eyewitnesses. *Acta Psychologica*, *139*(2), 320–326. https://doi.org/10.1016/j.actpsy.2011.12.004

Ganslmeier, M., Kunze, A. E., Ehring, T., & Wolkenstein, L. (2022). The dilemma of trauma-focused therapy: effects of imagery rescripting on voluntary memory. *Psychological Research*, *87*(5), 1616–1631. https://doi.org/10.1007/s00426-022-01746-z

Ganslmeier, M., Ehring, T., & Wolkenstein, L. (2023). Effects of imagery rescripting and imaginal exposure on voluntary memory. *Behaviour Research and Therapy*, *170*, 104409. https://doi.org/10.1016/j.brat.2023.104409

Garry, M., Manning, C. G., Loftus, E. F., & Sherman, S. J. (1996). Imagination inflation: Imagining a childhood event inflates confidence that it occurred. *Psychonomic Bulletin and Review*, *3*(2), 208–214. https://doi.org/10.3758/BF03212420

Goff, L. M., & Roediger, H. L. (1998). Imagination inflation for action events: Repeated imaginings lead to illusory recollections. *Memory and Cognition*, *26*(1), 20–33. https://doi.org/10.3758/BF03211367

Goldfarb, D., Goodman, G. S., Wang, Y., Fisher, R. P., Vidales, D., Gonzalves, L. C., Wu, Y., Hartman, D., Qin, J., & Eisen, M. L. (2023). Adults' Memory for a Maltreatment-Related Childhood Experience: Interview Protocols. *Clinical Psychological Science*, *11*(1), 164–182. https://doi.org/10.1177/21677026221081877

Golkar, A., Tjaden, C., & Kindt, M. (2017). Vicarious extinction learning during reconsolidation neutralizes fear memory. *Behaviour research and therapy*, *92*, 87-93.

Grey, N., & Holmes, E. A. (2008). "Hotspots" in trauma memories in the treatment of post-traumatic stress disorder: A replication. *Memory*, *16*(7), 788–796. https://doi.org/10.1080/09658210802266446

Gros, D. F., Price, M., Strachan, M., Yuen, E. K., Milanak, M. E., & Acierno, R. (2012). Behavioral Activation and Therapeutic Exposure: An Investigation of Relative Symptom Changes in PTSD and Depression During the Course of Integrated Behavioral Activation, Situational Exposure, and Imaginal Exposure Techniques. *Behavior Modification*, *36*(4), 580–599. https://doi.org/10.1177/0145445512448097

Haag, C., Robinaugh, D. J., Ehlers, A., & Kleim, B. (2017). Understanding the emergence of chronic posttraumatic stress disorder through acute stress symptom networks. *JAMA Psychiatry*, *74*(6), 649–650. https://doi.org/10.1001/jamapsychiatry.2017.0788

Hackmann, A., Ehlers, A., Speckens, A., & Clark, D. M. (2004). Characteristics and content of intrusive memories in PTSD and their changes with treatment. *Journal of Traumatic Stress*, *17*(3), 231–240. https://doi.org/10.1023/B:JOTS.0000029266.88369.fd

Hagenaars, M. A., & Arntz, A. (2012). Reduced intrusion development after post-trauma imagery rescripting; An experimental study. *Journal of Behavior Therapy and Experimental Psychiatry*, *43*(2), 808–814. https://doi.org/10.1016/j.jbtep.2011.09.005

Hagenaars, M. A., Van Minnen, A., & Hoogduin, K. A. L. (2009). Reliving and disorganization in posttraumatic stress disorder and panic disorder memories. *Journal of Nervous and Mental Disease*, *197*(8), 627–630. https://doi.org/10.1097/NMD.0b013e3181b08bdf

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

Herbert, J. D., Lilienfeld, S. O., Lohr, J. M., Montgomery, R. W., O'Donohue, W. T., Rosen, G. M., & Tolin, D. F. (2000). Science and pseudoscience in the development of eye movement desensitization and reprocessing: Implications for clinical psychology. *Clinical Psychology Review*, *20*(8), 945–971. https://doi.org/10.1016/S0272-7358(99)00017-3

Holmes, E. A., Brewin, C. R., & Hennessy, R. G. (2004). Trauma Films, Information Processing, and Intrusive Memory Development. *Journal of Experimental Psychology: General*, *133*(1), 3–22. https://doi.org/10.1037/0096-3445.133.1.3

Holmes, E. A., Ghaderi, A., Eriksson, E., Lauri, K. O., Kukacka, O. M., Mamish, M., James, E. L., & Visser, R. M. (2017). "I Can't Concentrate": A Feasibility Study with Young Refugees in Sweden on Developing Science-Driven Interventions for Intrusive

Memories Related to Trauma. *Behavioural and Cognitive Psychotherapy, 45*(2), 97–109. https://doi.org/10.1017/S135246581600062X

Horselenberg, R., Merckelbach, H., Muris, P., Rassin, E., Sijsenaar, M., & Spaan, V. (2000). Imagining fictitious childhood events: The role of individual differences in imagination inflation. *Clinical Psychology & Psychotherapy: An International Journal of Theory & Practice, 7*(2), 128-137.

Houben, S. T., Otgaar, H., Roelofs, J., & Merckelbach, H. (2018). Lateral eye movements increase false memory rates. *Clinical Psychological Science, 6*(4), 610-616.

Houben, S. T. L., Otgaar, H., Roelofs, J., Smeets, T., & Merckelbach, H. (2020). Increases of correct memories and spontaneous false memories due to eye movements when memories are retrieved after a time delay. *Behaviour Research and Therapy, 125*, 103546. https://doi.org/10.1016/j.brat.2019.103546

Houben, S. T. L., Otgaar, H., Roelofs, J., Wessel, I., Patihis, L., & Merckelbach, H. (2021). Eye Movement Desensitization and Reprocessing (EMDR) Practitioners' Beliefs About Memory. *Psychology of Consciousness: Theory Research, and Practice, 8*(3), 258–273. https://doi.org/10.1037/cns0000211

Van den Hout, M. A., Bartelski, N., & Engelhard, I. M. (2013). On EMDR: Eye movements during retrieval reduce subjective vividness and objective memory accessibility during future recall. *Cognition & Emotion, 27*(1), 177-183.

Huffman, M. L., Crossman, A. M., & Ceci, S. J. (1997). "Are False Memories Permanent?": An Investigation of the Long-Term Effects of Source Misattributions. *Consciousness and Cognition, 6*(4), 482–490. https://doi.org/10.1006/ccog.1997.0316

Iyadurai, L., Visser, R. M., Lau-Zhu, A., Porcheret, K., Horsch, A., Holmes, E. A., & James, E. L. (2019). Intrusive memories of trauma: A target for research bridging cognitive science and its clinical application. *Clinical Psychology Review, 69*, 67–82. https://doi.org/10.1016/j.cpr.2018.08.005

Jahn, V. R. M., Frankfurt, M., Nestor, V., & Strafprozeßrechtswissenschaft, D. (2001). *Grundlagen der Beweiswürdigung Glaubhaftigkeitsbeurteilung im Strafverfahren. 138*, 1–15.

James, E. L., Bonsall, M. B., Hoppitt, L., Tunbridge, E. M., Geddes, J. R., Milton, A. L., & Holmes, E. A. (2015). Computer Game Play Reduces Intrusive Memories of Experimental Trauma via Reconsolidation-Update Mechanisms. *Psychological Science, 26*(8), 1201–1215. https://doi.org/10.1177/0956797615583071

James, E. L., Lau-Zhu, A., Clark, I. A., Visser, R. M., Hagenaars, M. A., & Holmes, E. A. (2016). The trauma film paradigm as an experimental psychopathology model of psychological trauma: intrusive memories and beyond. *Clinical Psychology Review, 47*, 106–142. https://doi.org/10.1016/j.cpr.2016.04.010

Janet, P. (1919). *Les médications psychologiques: études historiques, psychologiques et cliniques sur les méthodes de la psychothérapie* (Vol. 3). F. Alcan.

Jelinek, L., Randjbar, S., Seifert, D., Kellner, M., & Moritz, S. (2009). The Organization of Autobiographical and Nonautobiographical Memory in Posttraumatic Stress Disorder (PTSD). *Journal of Abnormal Psychology, 118*(2), 288–298. https://doi.org/10.1037/a0015633

Jelinek, L., Stockbauer, C., Randjbar, S., Kellner, M., Ehring, T., & Moritz, S. (2010).

Characteristics and organization of the worst moment of trauma memories in posttraumatic stress disorder. *Behaviour Research and Therapy*, *48*(7), 680–685. https://doi.org/10.1016/j.brat.2010.03.014

Jellestad, L., Zeffiro, T., Piccirelli, M., Malamud, J., Klimke, B. B. M., Rauen, K., Rufer, M., Orr, S. P., & Mueller-Pfeiffer, C. (2021). Interfering with fear memories by eye movement desensitization and reprocessing. *International Journal of Psychophysiology*, *166*, 9–18. https://doi.org/10.1016/j.ijpsycho.2021.04.006

Johnson, M. K., Hashtroudi, S., & Lindsay, D. S. (1993). Source monitoring. *Psychological bulletin, 114*(1), 3.

Johnson, M. K., & Raye, C. L. (1981). Reality monitoring. *Psychological Review*, *88*(1), 67–85. https://doi.org/10.1037//0033-295x.88.1.67

Jones, C., Harvey, A. G., & Brewin, C. R. (2007). *The organisation and content of trauma memories in survivors of road traffic accidents*. *45*(1), 151–162. https://doi.org/10.1016/j.brat.2006.02.004

Karanian, J. M., Rabb, N., Wulff, A. N., Torrance, M. G., Thomas, A. K., & Race, E. (2020). Protecting memory from misinformation: Warnings modulate cortical reinstatement during memory retrieval. *Proceedings of the National Academy of Sciences of the United States of America*, *117*(37), 22771–22779. https://doi.org/10.1073/pnas.2008595117

Karpel, M. E., Hoyer, W. J., & Toglia, M. P. (2001). Accuracy and qualities of real and suggested memories: Nonspecific age differences. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *56*(2), P103-P110.

Kaur, K., Asnaani, A., Levy, H. C., Miller, M. L., Tolin, D. F., & McLean, C. P. (2024). Moving beyond symptom reduction: A meta-analysis on the effect of exposure therapy for PTSD on quality of life. *Journal of Clinical Psychology, 80,* 2134–2146.

Kazdin, A. E. (2009). Understanding how and why psychotherapy leads to change. *Psychotherapy Research*, *19*(4–5), 418–428. https://doi.org/10.1080/10503300802448899

Kindt, M., Buck, N., Arntz, A., & Soeter, M. (2007). Perceptual and conceptual processing as predictors of treatment outcome in PTSD. *Journal of Behavior Therapy and Experimental Psychiatry*, *38*(4), 491–506. https://doi.org/10.1016/j.jbtep.2007.10.002

Kindt, M., & Elsey, J. W. B. (2023). A paradigm shift in the treatment of emotional memory disorders: Lessons from basic science. *Brain Research Bulletin, 192,* 168–174. https://doi.org/10.1016/j.brainresbull.2022.11.019

Kindt, M., & Soeter, M. (2018). Pharmacologically induced amnesia for learned fear is time and sleep dependent. *Nature communications, 9*(1), 1316.

Kindt, M., & Soeter, M. (2007). Perceptual and conceptual processing as predictors of treatment outcome in PTSD. *Journal of Behavior Therapy and Experimental Psychiatry, 38,* 491–509. https://doi.org/10.1016/j.jbtep.2007.10.002

Kip, A., Schoppe, L., Arntz, A., & Morina, N. (2023). Efficacy of imagery rescripting in treating mental disorders associated with aversive memories-an updated meta-analysis. *Journal of Anxiety Disorders*, 102772.

Kirschbaum, C., Pirke, K.-M., & Hellhammer, D. H. (1993). The "Trier Social Stress Test" - A Tool for Investigating Psychobiological Stress Responses in a Laboratory Setting.

Neuropsychobiology, *28*, 76–81. https://doi.org/10.1159/000119004

Kleim, B., Ehlers, A., & Glucksman, E. (2007). Early predictors of chronic post-traumatic stress disorder in assault survivors. *Psychological Medicine, 37*(10), 1457–1467. https://doi.org/10.1017/S0033291707001006

Kunze, A. E., Arntz, A., & Kindt, M. (2019). Investigating the effects of imagery rescripting on emotional memory: A series of analogue studies. *Journal of Experimental Psychopathology, 10*(2), 204380871985073. https://doi.org/10.1177/2043808719850733

Lau-Zhu, A., Henson, R. N., & Holmes, E. A. (2019). Intrusive memories and voluntary memory of a trauma film: Differential effects of a cognitive interference task after encoding. Journal of Experimental Psychology: *General*, *148*(12), 2154.

Leding, J. K., & Antonio, L. (2019). Need for cognition and discrepancy detection in the misinformation effect. *Journal of Cognitive Psychology*, *31*(4), 409–415. https://doi.org/10.1080/20445911.2019.1626400

Lee, C. W., & Cuijpers, P. (2013). A meta-analysis of the contribution of eye movements in processing emotional memories. *Journal of Behavior Therapy and Experimental Psychiatry, 44*(2), 231–239. https://doi.org/10.1016/j.jbtep.2012.11.001

Lee, D. J., Schnitzlein, C. W., Wolf, J. P., Vythilingam, M., Rasmusson, A. M., & Hoge, C. W. (2016). Psychotherapy Versus Pharmacotherapy for Posttraumatic Stress Disorder: Systemic Review and Meta-Analyses To Determine First-Line Treatments. *Depression and Anxiety*, *33*(9), 792–806. https://doi.org/10.1002/da.22511

Lee, S. W., & Kwon, J. H. (2013). The efficacy of Imagery Rescripting (IR) for social phobia: A randomized controlled trial. *Journal of Behavior Therapy and Experimental Psychiatry*, *44*(4), 351–360. https://doi.org/10.1016/j.jbtep.2013.03.001

Leer, A., & Engelhard, I. M. (2020). Side effects of induced lateral eye movements during aversive ideation. *Journal of Behavior Therapy and Experimental Psychiatry*, *68,* 101566. https://doi.org/10.1016/j.jbtep.2020.101566

Leer, A., Engelhard, I. M., Lenaert, B., Struyf, D., Vervliet, B., & Hermans, D. (2017). Eye movement during recall reduces objective memory performance: An extended replication. *Behaviour Research and Therapy*, *92*, 94–105. https://doi.org/10.1016/j.brat.2017.03.002

Li, C., Wang, J., & Otgaar, H. (2020). Creating nonbelieved memories for bizarre actions using an imagination inflation procedure. *Applied Cognitive Psychology*, *34*(6), 1277–1286. https://doi.org/10.1002/acp.3722

Lindsay, D. S., & Johnson, M. K. (2000). False memories and the source monitoring framework: Reply to Reyna and Lloyd (1997). *Learning and Individual Differences*, *12*(2), 145–161. https://doi.org/10.1016/S1041-6080(01)00035-8

Loftus, E. F. (1992). When A Lie Becomes Memory's Truth: Memory Distortion After Exposure to Misinformation. *Current Directions in Psychological Science*, *1*(4), 121–123. https://doi.org/10.1111/1467-8721.ep10769035

Loftus, E. F. (1997). Creating False Memories. *Scientific American 277 (3), 70-75.*, *277*(3), 70–75.

Loftus, E. F. (2005). Planting misinformation in the human mind: A 30-year investigation of the malleability of memory. *Learning and Memory*, *12*(4), 361–366.

https://doi.org/10.1101/lm.94705

Loftus, E. F., & Davis, D. (2006). Recovered memories. *Annual Review of Clinical Psychology, 2,* 469–498. https://doi.org/10.1146/annurev.clinpsy.2.022305.095315

Loftus, E. F., & Klemfuss, J. Z. (2023). Misinformation–past, present, and future. *Psychology, Crime and Law*. https://doi.org/10.1080/1068316X.2023.2219813

Loftus, E. F., Miller, D. G., & Burns, H. J. (1978). Semantic integration of verbal information into a visual memory. *Journal of Experimental Psychology: Human Learning and Memory*, *4*(1), 19–31. https://doi.org/10.1037/0278-7393.4.1.19

Loftus, E., & Pickerell, J. E. (1995). The Formation of False Memories (early version). *Psychiactric Annals*, *25*(12), 720–725.

Lövdén, M. (2003). The episodic memory and inhibition accounts of age-related increases in false memories: A consistency check. *Journal of Memory and Language, 49*(2), 268–283. https://doi.org/10.1016/S0749-596X(03)00069-X

Lyle, K. B., & Johnson, M. K. (2007). Source misattributions may increase the accuracy of source judgments. *Memory and Cognition*, *35*(5), 1024–1033. https://doi.org/10.3758/BF03193475

Lynn, S. J., Krackow, E., Loftus, E. F., Locke, T. G., & Lilienfeld, S. O. (2015). Constructing the past: Problematic memory recovery techniques in psychotherapy. In S. O. Lilienfeld, S. J. Lynn, & J. M. Lohr (Eds.), *Science and pseudoscience in clinical psychology* (2nd ed., pp. 210–244). The Guilford Press.

Lynn, S. J., McNally, R. J., & Loftus, E. F. (2023). The Memory Wars Then and Now: The Contributions of Scott O. Lilienfeld. *Clinical Psychological Science*, *11*(4), 725–743. https://doi.org/10.1177/21677026221133034

Malloggi, S., Conte, F., De Rosa, O., Righi, S., Gronchi, G., Ficca, G., & Giganti, F. (2022). False memories formation is increased in individuals with insomnia. *Journal of Sleep Research*, *31*(3), 1–12. https://doi.org/10.1111/jsr.13527

Matthews, S. R., Elizabeth, M., Roberts, L. N., & Nixon, R. D. V. (2022). Client Versus Clinicians' Standards of Clinically Meaningful Change and the Effects of Treatment Expectations on Therapeutic Outcomes in Individuals With Posttraumatic Stress Disorder. *Behavior Therapy*, *53*(3), 560–570. https://doi.org/10.1016/j.beth.2021.12.007

Matthijssen, S. J. M. A., Lee, C. W., de Roos, C., Barron, I. G., Jarero, I., Shapiro, E., Hurley, E. C., Schubert, S. J., Baptist, J., Amann, B. L., Moreno-Alcázar, A., Tesarz, J., & de Jongh, A. (2020). The Current Status of EMDR Therapy, Specific Target Areas, and Goals for the Future. *Journal of EMDR Practice and Research*, *14*(4), 241–284. https://doi.org/10.1891/EMDR-D-20-00039

Maxfield, L., Melnyk, W. T., & Hayman, G. C. A. (2008). A Working Memory Explanation for the Effects of Eye Movements in EMDR. *Journal of EMDR Practice and Research*, *2*(4), 247–261. https://doi.org/10.1891/1933-3196.2.4.247

Mazzoni, G., & Memon, A. (2003). Imagination can create false autobiographical memories. *Psychological Science*, *14*(2), 186–188. https://doi.org/10.1046/j.1432-1327.2000.01821.x

McNally, R. J. (2012). The Ontology of Posttraumatic Stress Disorder: Natural Kind, Social Construction, or Causal System? *Clinical Psychology: Science and Practice*, *19*(3), 220–

228. https://doi.org/10.1111/cpsp.12001

Meckling, H. I., Nauta, M. H., van Hout, W. J. P. J., & Wessel, I. (2024). The effects of eye movements on the content and characteristics of unpleasant autobiographical memories: an extended replication study. *Memory*, 1–19. https://doi.org/10.1080/09658211.2024.2307925

Michael, T., Ehlers, A., Halligan, S. L., & Clark, D. M. (2005). Unwanted memories of assault: What intrusion characteristics are associated with PTSD? *Behaviour Research and Therapy*, *43*(5), 613–628. https://doi.org/10.1016/j.brat.2004.04.006

Mills, K. (2006). Trauma, PTSD, and Substance Use Disorders: Findings From the Australian National Survey of Mental Health and Well-Being. *American Journal of Psychiatry*, *163*(4), 652. https://doi.org/10.1176/appi.ajp.163.4.652

Moradi, A. R., Heydari, A. H., Abdollahi, M. H., Rahimi-Movaghar, V., Dalgleish, T., & Jobson, L. (2015). Visual false memories in posttraumatic stress disorder. *Journal of Abnormal Psychology*, *124*(4), 905.

Morin, J. F. G., Afzali, M. H., Bourque, J., Stewart, S. H., Séguin, J. R., O'Leary-Barrett, M., & Conrod, P. J. (2019). A population-based analysis of the relationship between substance use and adolescent cognitive development. *American Journal of Psychiatry*, *176*(2), 98–106. https://doi.org/10.1176/appi.ajp.2018.18020202

Morina, N., Lancee, J., & Arntz, A. (2017). Imagery rescripting as a clinical intervention for aversive memories: A meta-analysis. *Journal of Behavior Therapy and Experimental Psychiatry*, *55*, 6–15. https://doi.org/10.1016/j.jbtep.2016.11.003

Murayama, K., Miyatsu, T., Buchli, D., & Storm, B. C. (2014). Forgetting as a consequence of retrieval: A meta-analytic review of retrieval-induced forgetting. *Psychological Bulletin*, *140*(5), 1383–1409. https://doi.org/10.1037/a0037505

Nadel, L., Campbell, J., & Ryan, L. (2007). Autobiographical memory retrieval and hippocampal activation as a function of repetition and the passage of time. *Neural Plasticity*, *2007*. https://doi.org/10.1155/2007/90472

Nader, K., Schafe, G. E., & Le Doux, J. E. (2000). Fear memories require protein synthesis in the amygdala for reconsolidation after retrieval. *Nature, 406*(6797), 722-726.

Odinot, G., Wolters, G., & van Giezen, A. (2013). Accuracy, confidence and consistency in repeated recall of events. *Psychology, Crime and Law*, *19*(7), 629–642. https://doi.org/10.1080/1068316X.2012.660152

Oeberst, A., & Blank, H. (2012). Undoing suggestive influence on memory: The reversibility of the eyewitness misinformation effect. *Cognition*, *125*(2), 141–159. https://doi.org/10.1016/j.cognition.2012.07.009

Oeberst, A., Wachendörfer, M. M., Imhoff, R., & Blank, H. (2021). Rich false memories of autobiographical events can be reversed. *Proceedings of the National Academy of Sciences, 118*(13), e2026447118.

Ohayon, M. M., & Shapiro, C. M. (2000). Posttraumatic stress disorder in the general population. *Comprehensive psychiatry, 41*(6), 469-478.

Olatunji, B. O., Cisler, J. M., & Tolin, D. F. (2007). Quality of life in the anxiety disorders: A meta-analytic review. *Clinical Psychology Review*, *27*(5), 572–581. https://doi.org/10.1016/j.cpr.2007.01.015

Otgaar, H., Houben, S. T., & Howe, M. L. (2018). Methods of studying false memory. In *Handbook of research methods in human memory* (pp. 238-252). Routledge.

Otgaar, H., Candel, I., Smeets, T., & Merckelbach, H. (2010). "You didn't take Lucy's skirt off": The effect of misleading information on omissions and commissions in children's memory reports. *Legal and Criminological Psychology*, *15*(2), 229–241. https://doi.org/10.1348/135532509X471951

Otgaar, H., Houben, S. T. L., Rassin, E., & Merckelbach, H. (2021). Memory and eye movement desensitization and reprocessing therapy: a potentially risky combination in the courtroom. *Memory*, *29*(9), 1254–1262. https://doi.org/10.1080/09658211.2021.1966043

Otgaar, H., Muris, P., Howe, M. L., & Merckelbach, H. (2017). What Drives False Memories in Psychopathology? A Case for Associative Activation. *Clinical Psychological Science*, *5*(6), 1048–1069. https://doi.org/10.1177/2167702617724424

Parry, L., & O'Kearney, R. (2014). A comparison of the quality of intrusive memories in post-traumatic stress disorder and depression. *Memory*, *22*(4), 408–425. https://doi.org/10.1080/09658211.2013.795975

Peace, K. A., & Porter, S. (2004). A longitudinal investigation of the reliability of memories for trauma and other emotional experiences. *Applied Cognitive Psychology*, *18*(9), 1143–1159. https://doi.org/10.1002/acp.1046

Pearson, J., Naselaris, T., Holmes, E. A., & Kosslyn, S. M. (2015). Mental Imagery: Functional Mechanisms and Clinical Applications. *Trends in Cognitive Sciences*, *19*(10), 590–602. https://doi.org/10.1016/j.tics.2015.08.003

Phelps, A. J., Lethbridge, R., Brennan, S., Bryant, R. A., Burns, P., Cooper, J. A., ... & Silove, D. (2022). Australian guidelines for the prevention and treatment of posttraumatic stress disorder: Updates in the third edition. *Australian & New Zealand Journal of Psychiatry*, *56*(3), 230-247.

Pitel, A. L., Beaunieux, H., Witkowski, T., Vabret, F., Guillery-Girard, B., Quinette, P., Desgranges, B., & Eustache, F. (2007). Genuine episodic memory deficits and executive dysfunctions in alcoholic subjects early in abstinence. *Alcoholism: Clinical and Experimental Research*, *31*(7), 1169–1178. https://doi.org/10.1111/j.1530-0277.2007.00418.x

Porter, S., Taylor, K., & ten Brinke, L. (2008). Memory for media: Investigation of false memories for negatively and positively charged public events. *Memory*, *16*(6), 658–666. https://doi.org/10.1080/09658210802154626

Powers, M. B., Halpern, J. M., Ferenschak, M. P., Gillihan, S. J., & Foa, E. B. (2013). A meta-analytic review of prolonged exposure for posttraumatic stress disorder. *FOCUS*, *11*(3), 428-436.

Rameckers, S. A., van Emmerik, A. A., de Haan, K. B., Kousemaker, M., Fassbinder, E., Lee, C. W., ... & Arntz, A. (2024). The working mechanisms of imagery rescripting and eye movement desensitization and reprocessing: Findings from a randomised controlled trial. *Behaviour Research and Therapy, 175*, 104492.

Rattel, J. A., Danböck, S., Miedl, S. F., Liedlgruber, M., & Wilhelm, F. H. (2024). Hitting the Rewind Button: Imagining Analogue Trauma Memories in Reverse Reduces Distressing Intrusions. *Cognitive Therapy and Research*, *48*(5), 932–943.

https://doi.org/10.1007/s10608-024-10488-8

Rattel, J. A., Miedl, S. F., Franke, L. K., Grünberger, L. M., Blechert, J., Kronbichler, M., Spoormaker, V. I., & Wilhelm, F. H. (2019). Peritraumatic Neural Processing and Intrusive Memories: The Role of Lifetime Adversity. *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging*, *4*(4), 381–389. https://doi.org/10.1016/j.bpsc.2018.12.010

Rauch, S., & Foa, E. (2006). Emotional processing theory (EPT) and exposure therapy for PTSD. *Journal of Contemporary Psychotherapy*, *36*(2), 61–65. https://doi.org/10.1007/s10879-006-9008-y

Roediger, H. L., & McDermott, K. B. (1995). Creating false memories: Remembering words not presented in lists. *Journal of experimental psychology: Learning, Memory, and Cognition*, *21*(4), 803.

Rubin, D. C. (2011). The coherence of memories for trauma: Evidence from posttraumatic stress disorder. *Consciousness and Cognition*, *20*(3), 857–865. https://doi.org/10.1016/j.concog.2010.03.018

Rubin, D. C., Deffle, S. A., Ogle, C. M., Dowell, N. M., Graesser, A. C., & Beckham, J. C. (2016). Participant, rater, and computer measures of coherence in posttraumatic stress disorder. *Journal of Abnormal Psychology*, *125*(1), 11–25. https://doi.org/10.1037/abn0000126

Rusch, M. D., Grunert, B. K., Mendelsohn, R. A., & Smucker, M. R. (2000). Imagery rescripting for recurrent, distressing images. *Cognitive and Behavioral Practice*, *7*(2), 173-182.

Schäfer, S. K., Becker, N., King, L., Horsch, A., & Michael, T. (2019). The relationship between sense of coherence and post-traumatic stress: a meta-analysis. *European Journal of Psychotraumatology*, *10*(1). https://doi.org/10.1080/20008198.2018.1562839

Schäfer, I., Ehring, T., Knaevelsrud, C., Maercker, A. R. A., Michael, T., & Schellong, J. (2020). Diagnostics and treatment of posttraumatic stress disorder: Recommendations of the new S3 guidelines. *Psychotherapeut*, *65*, 521-532.

Schemmel, J., Datschewski-Verch, L., & Volbert, R. (2024). Recovered memories in psychotherapy: a survey of practicing psychotherapists in Germany. *Memory*, *32*(2), 176–196. https://doi.org/10.1080/09658211.2024.2305870

Schmidt, R. E., Richter, M., Gendolla, G. H. E., & Van Der Linden, M. (2010). Young poor sleepers mobilize extra effort in an easy memory task: Evidence from cardiovascular measures: Insomnia. *Journal of Sleep Research*, *19*(3), 487–495. https://doi.org/10.1111/j.1365-2869.2010.00834.x

Scoboria, A., Mazzoni, G., Kirsch, I., & Relyea, M. (2004). Plausibility and belief in autobiographical memory. *Applied Cognitive Psychology*, *18*(7), 791–807. https://doi.org/10.1002/acp.1062

Scoboria, A., Wade, K. A., Lindsay, D. S., Azad, T., Strange, D., Ost, J., & Hyman, I. E. (2017). A mega-analysis of memory reports from eight peer-reviewed false memory implantation studies. *Memory*, *25*(2), 146–163. https://doi.org/10.1080/09658211.2016.1260747

Sevenster, D., Beckers, T., & Kindt, M. (2012). Instructed extinction differentially affects the emotional and cognitive expression of associative fear memory. *Psychophysiology*, *49*(10), 1426–1435. https://doi.org/10.1111/j.1469-8986.2012.01450.x

Sevenster, D., Beckers, T., & Kindt, M. (2013). Prediction error governs pharmacologically induced amnesia for learned fear. *Science*, *339*(6121), 830–833. https://doi.org/10.1126/science.1231357

Shapiro, F. (1989). Eye movement desensitization: A new treatment for post-traumatic stress disorder. *Journal of behavior therapy and experimental psychiatry*, *20*(3), 211-217.

Shapiro, F. (2001). *Eye movement desensitization and reprocessing (EMDR): Basic principles, protocols, and procedures*. Guilford Press.

Siegesleitner, M., Strohm, M., Wittekind, C. E., Ehring, T., & Kunze, A. E. (2019). Effects of imagery rescripting on consolidated memories of an aversive film. *Journal of Behavior Therapy and Experimental Psychiatry*, *62*, 22–29. https://doi.org/10.1016/j.jbtep.2018.08.007

Smucker, M. R., Dancu, C., Foa, E. B., & Niederee, J. L. (1995). Imagery Rescripting: A New Treatment for Survivors of Childhood Sexual Abuse Suffering From Posttraumatic Stress. *Journal of Cognitive Psychotherapy*, *9*(1), 3–17.

Speckens, A. E. M., Ehlers, A., Hackmann, A., & Clark, D. M. (2006). Changes in intrusive memories associated with imaginal reliving in posttraumatic stress disorder. *Journal of Anxiety Disorders*, *20*(3), 328–341. https://doi.org/10.1016/j.janxdis.2005.02.004

Stark, C. E. L., Okado, Y., & Loftus, E. F. (2010). Imaging the reconstruction of true and false memories using sensory reactivation and the misinformation paradigms. *Learning and Memory*, *17*(10), 485–488. https://doi.org/10.1101/lm.1845710

Strohm, M., Siegesleitner, M., Kunze, A. E., Ehring, T., & Wittekind, C. E. (2019). Imagery Rescripting of Aversive Autobiographical Memories: Effects on Memory Distress, Emotions, and Feelings of Mastery. *Cognitive Therapy and Research*, *43*(6), 1005–1017. https://doi.org/10.1007/s10608-019-10021-2

Strohm, M., Siegesleitner, M., Kunze, A. E., Werner, G. G., Ehring, T., & Wittekind, C. E. (2021). Psychological and Physiological Effects of Imagery Rescripting for Aversive Autobiographical Memories. *Cognitive Therapy and Research*, *45*(6), 1093–1104. https://doi.org/10.1007/s10608-021-10233-5

Sutherland, R., & Hayne, H. (2001). The Effect of Postevent Information on Adults' Eyewitness Reports. *Applied Cognitive Psychology*, *15*(3), 249–263. https://doi.org/10.1002/acp.700

Thomas, A. K., Bulevich, J. B., & Loftus, E. F. (2003). Exploring the role of repetition and sensory elaboration in the imagination inflation effect. *Memory and Cognition*, *31*(4), 630–640. https://doi.org/10.3758/BF03196103

Tousignant, J. P., Hall, D., & Loftus, E. F. (1986). Discrepancy detection and vulnerability to misleading postevent information. *Memory & Cognition*, *14*(4), 329–338. https://doi.org/10.3758/BF03202511

Van der Hart, O., Brown, P., & Van der Kolk, B. A. (1989). Pierre Janet's treatment of post-traumatic stress. *Journal of traumatic stress*, *2*, 379-395.

van den Hout, M. A., Bartelski, N., & Engelhard, I. M. (2013). On EMDR: Eye movements during retrieval reduce subjective vividness and objective memory accessibility during future recall. *Cognition and Emotion*, *27*(1), 177–183.

https://doi.org/10.1080/02699931.2012.691087

van den Hout, M. A., & Engelhard, I. M. (2012a). How does EMDR work? *Journal of Experimental Psychopathology*, *3*(5), 724–738. https://doi.org/10.5127/jep.028212

van den Hout, M. A., & Engelhard, I. M. (2012b). How does EMDR work? *Journal of Experimental Psychopathology*, *3*(5), 724–738. https://doi.org/10.5127/jep.028212

Van Minnen, A., & Foa, E. B. (2006). The effect of imaginal exposure length on outcome of treatment for PTSD. *Journal of Traumatic Stress*, *19*(4), 427–438. https://doi.org/10.1002/jts.20146

Van Minnen, A., Wessel, I., Dijkstra, T., & Roelofs, K. (2002). Changes in PTSD patients' narratives during prolonged exposure therapy: A replication and extension. *Journal of Traumatic Stress, 15*(3), 255–258. https://doi.org/10.1023/A:1015263513654

Van Schie, K., & Leer, A. (2019). Lateral eye movements do not increase false-memory rates: A failed direct-replication study. *Clinical Psychological Science, 7*(5), 1159-1167.

Visser, R. M., Lau-Zhu, A., Henson, R. N., & Holmes, E. A. (2018). Multiple memory systems, multiple time points: How science can inform treatment to control the expression of unwanted emotional memories. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *373*(1742). https://doi.org/10.1098/rstb.2017.0209

Walter, K. H., Levine, J. A., Highfill-McRoy, R. M., Navarro, M., & Thomsen, C. J. (2018). Prevalence of Posttraumatic Stress Disorder and Psychological Comorbidities Among U.S. Active Duty Service Members, 2006–2013. *Journal of Traumatic Stress*, *31*(6), 837–844. https://doi.org/10.1002/jts.22337

Watts, B. V., Schnurr, P. P., Mayo, L., Young-Xu, Y., Weeks, W. B., & Friedman, M. J. (2013). Meta-analysis of the efficacy of treatments for posttraumatic stress disorder. *Journal of Clinical Psychiatry*, *74*(6), 541–550. https://doi.org/10.4088/JCP.12r08225

Woelk, M., Hagenaars, M. A., Raes, F., Vervliet, B., & Krans, J. (2024). Imagery rescripting and extinction: Effects on US expectancy, US revaluation, and the generalization of fear reduction. *Behaviour Research and Therapy*, *178*, 104544.

Wright, D. B., Loftus, E. F., & Hall, M. (2001). Now You See It; Now You Don't: Inhibiting Recall and Recognition of Scenes. *Applied Cognitive Psychology*, *15*(5), 471–482. https://doi.org/10.1002/acp.719

Xu, Z., Hu, J., & Wang, Y. (2023). Bilateral eye movements disrupt the involuntary perceptual representation of trauma-related memories. *Behaviour Research and Therapy, 165*, 104311.

Yunitri, N., Chu, H., Kang, X. L., Wiratama, B. S., Lee, T. Y., Chang, L. F., Liu, D., Kustanti, C. Y., Chiang, K. J., Chen, R., Tseng, P., & Chou, K. R. (2023). Comparative effectiveness of psychotherapies in adults with posttraumatic stress disorder: a network meta-analysis of randomised controlled trials. *Psychological Medicine, 53*(13), 6376–6388. https://doi.org/10.1017/S0033291722003737

Zappalà, A., Mangiulli, I., Santtila, P., Loftus, E. F., & Otgaar, H. (2024). Beliefs and therapeutic practices related to traumatic memories among Italian cognitive behavioral therapists and trainees. *Journal of Criminal Psychology, 14*(1), 24-37.