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Does treating emotional memories come at a price? Effects of single-session EMDR, imaginal exposure, and imagery rescripting on forced-choice recognition of event details in healthy adults – a laboratory study

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A R T I C L E I N F O

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A B S T R A C T

Eye Movement Desensitization and Reprocessing (EMDR), Imaginal Exposure (IE), and Imagery Rescripting (ImRs) are effective trauma-focused interventions. However, concerns persist that they may impair the accuracy of memories addressed in treatment. This laboratory study tested whether a single session of EMDR, IE, or ImRs affects forced-choice recognition in healthy adults.

Two hundred sixty-five participants underwent the Trier Social Stress Test (TSST) and received EMDR, IE, ImRs, or no intervention (NIC) the following day. One week later, memory for the TSST was assessed using a forced-choice recognition task (one target; three plausible foils).

Contrary to expectations, the interventions did not differentially affect recognition performance; the number of correct answers was comparable to NIC across intervention groups. For ImRs and IE, this aligns with recent findings suggesting that they do not impair recognition memory. For EMDR, prior experimental studies linked eye movements to poorer delayed free recall, stimulus discrimination, and yes/no recognition. Here, we observed no impairment in delayed forced-choice recognition, suggesting that previously reported negative effects may not generalize across memory outcomes or task formats.

Overall, these findings indicate that trauma-focused interventions do not carry a *general* risk of memory impairment. However, conclusions are limited by the laboratory analogue design, exclusive reliance on a recognition task, and the absence of treatment-integrity checks, which raises the possibility that null effects reflect limited intervention effectiveness. Future research should specify conditions under which these interventions may pose risks, clarify mechanisms underlying task- and memory-specific effects, and examine how findings generalize to clinical populations.

1. Introduction

Persistent and distressing emotional memories are central to the development and maintenance of various psychological disorders, most notably posttraumatic stress disorder (PTSD). Interventions that directly target these memories have demonstrated strong clinical efficacy and are recommended as first-line treatments for PTSD in international guidelines (e.g., APA, 2017; Phelps et al., 2022). These include trauma-focused cognitive behavioral therapy (TF-CBT), which typically incorporates prolonged imaginal exposure (IE; Foa et al., 1989) and Eye Movement Desensitization and Reprocessing (EMDR, Shapiro, 1989; 2017). Increasing empirical evidence also supports the efficacy of Imagery Rescripting (ImRs; Arntz & Weertman, 1999; Smucker et al., 1995), although it has not yet been included in treatment guidelines (e.g., Kip et al., 2023; Morina et al., 2017).

All three interventions require intensive engagement with the traumatic memory through imaginative techniques. IE involves repeated mental reliving of the trauma until distress declines. In ImRs, patients imaginatively revisit their memory and change its course to create a less distressing outcome (e.g., confronting the perpetrator and taking care of the victim's needs). EMDR combines memory recall with bilateral stimulation, usually through horizontal eye movements. The shared aim of these interventions is to modify the emotional quality of trauma memories and to reduce their intrusive retrieval. Indeed, prior research

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indicates they can effectively do so (e.g., Schäfer et al., 2019; Kip et al., 2023). However, concerns have been raised that these interventions might inadvertently impair the accurate recall of factual event details (e.g., Ganslmeier et al., 2022, 2023; Otgaar et al., 2021).

These concerns are rooted in decades of experimental research showing that memory is fallible and can be distorted under various conditions, resulting in *false memories* – i.e., recollections of events or details that are inaccurate or entirely fabricated (Davis & Loftus, 2020, pp. 884–893; Loftus, 1997, 2005). A variety of experimental paradigms have been developed to examine the mechanisms underlying false memory formation. Here, we focus on those paradigms that have been directly referenced in the context of potential adverse memory effects of trauma-focused interventions.

A well-established example is the „misinformation effect" where memory is altered by exposure to misleading post-event information (see Loftus & Klemfuss, 2024 for an overview). Typically, participants witness an event and are later presented with incorrect information through suggestive questions (e.g., Loftus, 1997) or post-event narratives presented as authentic accounts of the event (e.g., Stark et al., 2010). Subsequent memory tests then typically assess two possible outcomes (cf. Blank & Launy, 2014): impaired memory of event details (e.g., Belli, 1989; Loftus et al., 1978; Geiselman et al., 1986) and/or incorporation of misinformation into the memory (e.g., Higham, 1998; Lindsay, 1990; Loftus & Klemfuss, 2024; Zaragoza & Lane, 1994).

In addition, false memories can also arise without external suggestion. For instance, the "imagination inflation effect" (Garry et al., 1996; Goff & Roediger, 1998) shows that vividly imagining an event can increase confidence that it occurred, even if it did not (e.g., Mazzoni & Memon, 2003; Thomas & Loftus, 2002). Imagination has also been found to distort existing memories (Goff & Roediger, 1998; Lyle & Johnson, 2007). Additionally, spontaneous false memories may also result from associative activation (Otgaar et al., 2016), as demonstrated in the Deese-Roediger-McDermott (DRM) paradigm (Deese, 1959; Roediger & McDermott, 1995), where studying lists of related words (e.g., bed, rest, tired) often leads to the false recall or recognition of a semantically related but non-presented word (e.g., sleep; Cann et al., 2011; Otgaar et al., 2016).

These findings have raised concerns that trauma-focused interventions – particularly those involving imagination and/or memory modification – may pose similar risks of memory distortion. However, empirical research on this question remains limited. A key methodological challenge is that autobiographical memories – the typical target of such interventions – cannot be objectively verified. Analogue paradigms, where memories are experimentally induced, offer a valuable approach as they enable investigation of memory changes under controlled conditions. To ensure clinical relevance, however, these paradigms must also sufficiently capture relevant aspects of real-life emotional experiences. This includes accounting for the nature, emotional valence and salience of the targeted memories, as well as the timing and type of therapeutic instructions – all of which can influence memory outcomes.

In recent years, several studies have employed such paradigms to examine how trauma-focused interventions affect memory performance, primarily in non-clinical samples. Much of this work has focused on EMDR, particularly the role of its eye movement component, in false memory formation. This research was motivated by findings that eye movements can reduce the vividness and emotionality of negative memories (e.g., Kavanagh et al., 2001; Lee & Cuijpers, 2013; Leer et al., 2014), raising concerns that such memories might be more susceptible to distortion.

One line of research has tested whether eye movements increase vulnerability to suggestive influences using misinformation paradigms. In these studies, participants watched an aversive film clip depicting an accident and then performed eye movements while recalling the memory. Following the intervention, they received post-event information containing both accurate and misleading details and subsequently completed a recognition task. While Houben et al. (2018) found increased misinformation endorsement following eye movements, other studies failed to replicate this effect (e.g., Calvillo & Emami, 2019; Kenchel et al., 2022; van Schie & Leer, 2019).

A second line of research has examined whether eye movements increase the likelihood of spontaneously generated false memories that arise in the absence of misinformation. Methods in this area are more heterogeneous. Several studies employed stimulus discrimination tasks to test whether eye movements impair the ability to distinguish previously encoded targets from perceptually similar distractors. Using pictures of male faces, van den Hout et al. (2013) and Leer et al. (2017) found that while eye movements reduced discrimination speed, they did not affect memory accuracy in an immediate memory test. Building on this, Leer and Engelhard (2020) paired the pictures with mild electric shocks to enhance aversiveness and tested memory both immediately and after 24 h. False-positive rates increased only at the delayed test, suggesting a delayed effect of eye movements on memory accuracy. Similarly, using the DRM paradigm, Houben et al. (2020) found no immediate effects but reported increased rates of both correct and false memories in the eye movement condition after a 48-h delay.

In sum, while there is no consistent evidence for immediate memory impairment, some studies suggest that eye movements may increase the risk of spontaneous false memories over time. However, these findings are based on a limited number of studies with heterogeneous methods, and final conclusions cannot yet be drawn. Although introducing a delay between intervention and memory testing increases external validity, all existing studies administered eye movements shortly after encoding. Since trauma-focused interventions typically target autobiographical memories that have already undergone consolidation, it remains unclear whether these findings translate to the treatment of consolidated memories. A recent study by Meckling et al. (2024) addressed this gap by examining EMDR's effects on unpleasant autobiographical memories in a healthy sample and found no evidence of altered memory content. However, as with all studies using autobiographical material, memory accuracy cannot be objectively verified, warranting cautious interpretation.

Beyond EMDR, recent studies have also investigated whether IE and ImRs might lead to memory distortions. Most studies have employed the trauma film paradigm and focused on the question whether these interventions impair retrieval of original event details. However, the findings do not support such concerns. In fact, several studies report improved memory performance following IE in both free recall (Ganslmeier et al., 2023) and cued recall tasks (Siegesleitner et al., 2019), regardless of whether the intervention was applied immediately after memory induction (Hagenaars & Arntz, 2012) or after delays of 24 h (Siegesleitner et al., 2019), or six days (Ganslmeier et al., 2023b).

Similarly, although ImRs involves explicit instructions to modify memory content – and could in principle be conceptualized as introducing misinformation – no study to date has shown that it distorts factual memory content. On the contrary, prior studies consistently indicate that ImRs does not impair memory performance, across free recall, recognition, and cued recall tasks (e.g., Aleksic et al., 2024; Ganslmeier et al., 2023a; b; Hagenaars & Arntz, 2012; Reineck et al., in prep.; Siegesleitner et al., 2019), whether administered immediately after memory induction (Hagenaars & Arntz, 2012) or after a time delay that allowed for memory consolidation (e.g., Aleksic et al., 2024; Ganslmeier et al., 2023b; Reineck et al., in prep.). Some studies even report superior memory performance compared to no-intervention control groups (Aleksic et al., 2024; Ganslmeier et al., 2022; Hagenaars & Arntz, 2012; Reineck et al., in prep.). Moreover, experimental studies investigating specific risk conditions for memory distortion found no impairment in recognition performance – regardless of the original memory's quality (Aleksic et al., 2024), level of detail and vividness participants were instructed to include when imagining the changes, or the plausibility of those changes (Reineck et al., in prep.).

In summary, there is currently no evidence that ImRs and IE lead to distortions of factual memory content. In contrast, findings on EMDR suggest that it may increase the risk of spontaneous false memories when memory is assessed after a delay rather than immediately post-intervention. However, most EMDR studies have examined recently formed, unconsolidated memories, whereas research on IE and ImRs has predominantly focused on already consolidated memories. This methodological discrepancy underscores the need for studies that test these interventions under comparable conditions.

Moreover, most prior work has relied on film clips, conditioning procedures, or word lists to induce memories. While such paradigms offer high experimental control – which is essential for assessing intervention effects on memory accuracy – they may not sufficiently capture the complexity of the memories typically targeted in treatment. As Freund et al. (2025) note, such paradigms lack important episodic characteristics of autobiographical memories: participants remain passive observers, are unable to act within the scene, and may find it difficult to fully immerse themselves in the experience. Even when distress is successfully induced, the absence of personal agency limits the comparability to real autobiographical experiences. To address this limitation, the Trier Social Stress Test (TSST; Kirschbaum et al., 1993) has been proposed as a method to induce emotionally salient memories that more closely approximate autobiographical experiences in terms of personal involvement, while still allowing for experimental control over memory content (Freund et al., 2023, 2025). The TSST has also been used in prior research to induce memories for the purpose of studying recognition of objects or faces encountered during the TSST itself (e.g., Bierbrauer et al., 2021; Herten et al., 2017; Smeets et al., 2007). A study by Ganslmeier et al. (2023a) was the first to use the TSST to investigate potential adverse effects of ImRs on memory performance and found no evidence of memory distortion across free recall and cued recall tasks.

Building on this approach, the present study employed the TSST to induce an aversive autobiographical memory and to systematically examine the effects of IE, ImRs, and EMDR on performance in a forced-choice memory recognition task. In doing so, we aimed to address several limitations of prior research. First, in line with Ganslmeier et al. (2023a; see also Freund et al., 2023, 2025), we examined intervention effects on a memory formed through direct personal experience rather than passive observation. Second, to assess the impact of the interventions on sufficiently (re-)consolidated memories, memory induction, intervention and memory were distributed across three separate laboratory sessions. Third, rather than isolating the eye movement component, we investigated EMDR using an adapted version of Shapiro's (2001) eight-phase EMDR protocol to better reflect how the intervention is implemented in clinical settings.

1.1. 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 fewer correct answers in the memory recognition task compared to ImRs, IE and a no-intervention control group (NIC).
2. In light of several recently published studies reporting no adverse – and in some cases beneficial – effects of ImRs on memory performance (Aleksic et al., 2024; Ganslmeier et al., 2022, 2023; Reineck et al., in prep.), we revised our preregistered exploratory hypothesis and expected ImRs to be associated with more correct answers in the memory recognition task than IE and NIC.
3. Based on prior findings (Ganslmeier et al., 2023; Hagenaars & Arntz, 2012; Houben et al., 2018; Siegesleitner et al., 2019), we expected IE to result in more correct answers in the memory recognition task than NIC and EMDR.
4. Consistent 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 expected fewer TSST-related intrusions in all intervention groups compared to NIC in the week following memory induction.

2. Methods

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

2.1. 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 = 0.05) 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 = 0.05) 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.

Two thousand seventy-one 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 $\geq$ 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 h before testing, (h) more than three consumptions of alcohol within 24 h 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. Four hundred eighty-four 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. Eleven 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).

3. Materials

All materials are available at the Open Science Framework (htt

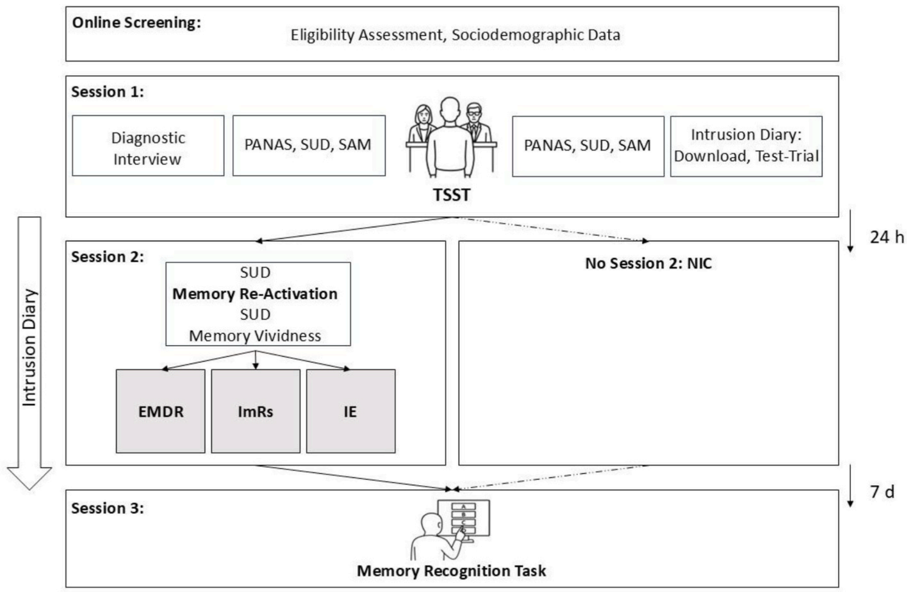

Fig. 1. Schematic overview of the study Procedure. *PANAS* positive and negative affect schedule, *SUD* subjective units of distress, *SAM* self-assessment manikin, *EMDR* eye movement desensitization and reprocessing, *ImRs* imagery rescripting, *IE* imaginal exposure, *NIC* No intervention control.

ps://osf.io/h3c7w/).

3.1. 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 3 min 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 1310), 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.

3.2. 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.

3.2.1. 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 to 10 had been reached, but at least for a minimum of 35 min and up to a maximum of 60 min. The exact wording of the instructions for memory reactivation can be found on the OSF (https://osf.io/h3c7w/).

3.2.2. 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 min was reached), ImRs was concluded. The exact wording of the instructions for ImRs can be found on the OSF (https://osf.io/h3c7w/).

3.2.3. 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 to 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 left to right (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 1 s), was presented on a light bar (length: 70 cm) during multiple episodes of a minimum of 24 *s* each. On average, participants completed M = 12.1 (SD = 5.15) sets. 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/).

3.2.4. Imaginal exposure

The IE intervention used in the study was adapted from Foa et al. (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/).

3.2.5. 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.

4. Measures

4.1. Screening measures to establish eligibility and assess sample characteristics

4.1.1. Demographic questionnaire

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

4.1.2. 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.

4.1.3. 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.

4.1.4. 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).

4.2. Manipulation checks

4.2.1. 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).

4.2.2. 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 to 10 post memory reactivation, as well as SUD pre- and post memory reactivation. The same measures were assessed at the end of each intervention.

4.3. Outcome measures

4.3.1. Memory accuracy - memory recognition task

Memory accuracy was assessed by means of a forced-choice memory recognition 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).

4.3.2. Memory confidence

We included subjective memory confidence as an exploratory measure to complement assessments of recognition performance. Prior research indicates that objective memory performance and memory confidence are not always strongly correlated (Odinot et al., 2013; Kurdi et al., 2018). To explore potential dissociations between these outcomes, participants rated their confidence after each recognition item on a scale from 0 (not at all sure) to 10 (absolutely sure) on a visual analogue scale.

4.3.3. 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).

4.4. Procedure

4.4.1. 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.

4.4.2. 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.

4.4.3. 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.

4.4.4. 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.

5. Results

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

5.1. Baseline and control variable differences between conditions

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). 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 $p_{adj.} < 0.001$. 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	0.63
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	0.97
	%	%	%	%		
Gender (female)	74,19	74,19	77,78	77,27	$\chi^2(6)$ = 2.26	0.89
German (yes)	72,58	79,03	82,54	75,76	$\chi^2(3)$ = 1.97	0.58
Student (yes)	95,15	91,93	88,89	93,94	$\chi^2(3)$ = 2.04	0.56
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	0.72
Sleep before Session 2	7.45 (1.02)	7.44 (1.22)	7.06 (1.44)	–	F(2,183) = 1.94	0.15
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	0.35
QUIDS-SR-16	4.60 (2.27)	5.19 (2.8)	4.87 (2.80)	5.08 (2.35)	F(3,249) = 0.65	0.59
STAI-T	37.81 (7.33)	39.31 (7.31)	38.37 (8.56)	39.80 (7.54)	F(3,249) = 0.87	0.46
STAI-S	38.29 (7.95)	38.95 (8.23)	38.13 (8.27)	38.45 (7.92)	F(3,249) = 0.12	0.95
Compliance Intrusion Diary	21.36 (25.86)	25.58 (29.83	18.22 (25.72)	21.36 (25.8)	F(3,249) = 2.06	0.11
Duration memory reactivation (in min.)	8.12 (2.97)	8.63 (2.86)	8.98 (2.69)	–	F (2,173) = 1.36	0.26
Duration intervention (in min.)	50.97 (11.99)	42.22 (8.53)	54.11 (7.84)	–	F (2, 173) = 24.11	<0.001

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.

5.2. Manipulation checks

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

5.2.1. Emotional distress caused by the TSST

Four 2 (pre-TSST vs. post-TSST) × 4 (group) mixed ANOVAs were conducted on SUD ratings, SAM ratings, and the two PANAS subscales to assess whether the TSST was experienced as distressing. A significant main effect of time indicated increased distress (SUD), arousal (SAM), and negative affect from pre-to post-TSST, (SUD: $F(1, 246) = 163.903$, $p < .001$, $\eta_p^2 = 0.4$, 95 % *CI* [0.31, 0.48]; SAM: $F(1, 248) = 460.513$, $p < .001$, $\eta_p^2 = 0.65$, 95 % *CI* [0.58, 0.70]; negative affect: $F(1, 249) = 280.714$, $p < .001$, $\eta_p^2 = 0.53$, 95 % *CI* [0.45, 0.59]). No main effects for intervention (all $Fs < 87$, all $ps > 0.46$, all $\eta_p^2 < 0.01$) and no interaction effects between time and intervention (all $Fs < 1.40$, all $ps > 0.24$, all $\eta_p^2 < 0.02$) emerged. For positive affect, no main effects of time, $F(1, 249) = 2.981$, $p = .09$, $\eta_p^2 = 0.01$ *CI* [0.00; 0.05] and intervention, $F(3, 249) = 0.46$, $p = .71$, $\eta_p^2 = 0.005$ *CI* [0.00; 0.02], and no interaction effect, $F(3, 249) = 0.303$, $p = .82$, $\eta_p^2 = 0.004$ *CI* [0.00; 0.02], emerged.

5.2.2. Memory reactivation pre-intervention in session 2

5.2.2.1. Subjective distress. A 2 (pre-reactivation vs. post-reactivation) x 4 (EMDR vs. IR vs. IE vs. NIC) mixed measures ANOVA (excluding 11 participants - IR: 3, IE: 5, EMDR: 2 - with missing data) 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

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)	–
SUD post intervention	1.32 (2.04)	0.98 (1.42)	3.32 (2.35)	
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.

effect $F(2, 173) = 0.69$, $p = .51$, $\eta_p^2 = 0.01$, 95 % *CI* [0.00, 0.04].

5.2.2.2. 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].

5.2.3. Reduction of subjective distress following the interventions

Subjective distress ratings decreased significantly across all groups from post-reactivation to post-intervention. A mixed ANOVA showed significant main effects of time, $F(1,160) = 418.43$, $p <. 001$, and intervention, $F(2,160) = 7.81$, $p <. 001$, as well as a significant time × intervention interaction, $F(2,160) = 9.81$, $p < .001$.

Post-hoc comparisons revealed significant reductions within each group (all $p <. 001$). After the intervention, EMDR and ImRs did not differ significantly ($p = 1.00$), whereas both groups showed significantly lower distress compared to IE ($p < .001$). See Table 2 for descriptive statistics.

5.3. Main analyses

Descriptive statistics for the results of the main analyses can be found in Table 3.

5.3.1. 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. No significant differences between groups were observed, $F(3, 249) = 2.293$, $p = .08$, $\eta^2 = 0.03$, 95 % CI [0.0, 0.07]. Descriptive statistics are presented 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)
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.

5.3.2. Intrusive memories

5.3.2.1. Baseline number of intrusive memories (pre-intervention). Due to violations of normality, a Kruskal-Wallis test was conducted to assess group differences in the baseline number of intrusive memories. No significant differences were observed, $H(3) = 253$, $p = .30$, $\eta^2 < 0.0$. A chi-square test revealed that the number of participants reporting no intrusive memories between Session 1 and Session 2 did not differ between groups, $\chi2(3) = 1.92$, $p = .59$.

5.3.2.2. Post intervention number of intrusive memories. No significant differences were observed in the number of intrusive memories post-intervention as determined by the Kruskal-Wallis test, $H(3) = 253$, $p = .59$, $\eta^2 < 0.0$. The number of participants who did not report any intrusive memories post-intervention did not differ between groups, $\chi2(3) = 4.43$, $p = .22$.

5.3.2.3. Development of intrusive memories over time. A two-level Poisson Regression Model with random intercepts and random slopes was estimated to examine the course of intrusive memories across days. 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. 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	<0.001
Time	−0.56 (0.18)	[-0.68; −0.43]	−8.71	<0.001
NIC vs. EMDR	0.64 (0.23)	[0.19; 1.09]	2.780	<0.001
NIC vs. ImRs	0.29 (0.23)	[-0.16; 0.74]	1.28	0.201
NIC vs. IE	0.45 (0.23)	[0.00; 0.89]	1.98	0.048
time: EMDR	−0.27 (0.09)	[-0.44; −0.10]	−3.15	0.002
time: ImRs	−0.04 (0.08)	[-0.20; 0.11]	−0.56	0.578
time: IE	−0.12 (0.08)	[-0.28; 0.04]	−1.48	0.140

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

5.4. Exploratory analyses

5.4.1. Memory confidence rating

A multivariate analysis of variance (MANOVA) assessed group differences in mean confidence ratings for correct and incorrect answers. No significant group differences were found, $F(3, 249) = 1.07$, $p = .38$, $\eta_p^2 = 0.01$, 95 % *CI* [0.00, 0.03], Pillai's Trace = 0.03. See Table 3 for descriptive statistics.

5.4.2. Intrusion distress and intrusion load

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. No significant effects of time were found for intrusion distress and intrusion load. However, reductions in intrusion distress and intrusion load were significantly greater in EMDR and in IE as compared to NIC. ImRs did not significantly differ from NIC.

Descriptive statistics are presented in Table S1 on the OSF (https://osf.io/a6n4u/); coefficient estimates, confidence intervals, and test statistics can be found in Tables 5 and 6.

6. 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 participants' memory for previously encoded aversive event details, as measured via a recognition task. 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 from a NIC with regard to their effects on memory recognition performance. Specifically, we did not find that ImRs was associated with better memory recognition, nor did we find that EMDR was associated with less accurate memories. Furthermore, we did not find any group differences in mean memory confidence ratings. Surprisingly, when looking at intervention efficacy, 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.

Table 5
Multilevel poisson regression model predicting the 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	<0.001
time	−1.45 (0.95)	[-3.31; 0.41]	−1.53	0.128
NIC vs. EMDR	12.73 (5.08)	[2.77; 22.69]	2.51	0.012
NIC vs. ImRs	0.97 (4.98)	[-8.79; 10.74]	0.20	0.845
NIC vs. IE	14.88 (4.89)	[5.29; 24.46]	3.05	0.002
time: EMDR	−5.49 (1.54)	[-8.51; −2.47]	−3.56	<0.001
time: ImRs	−2.01 (1.33)	[-4.62; 0.59]	−1.52	0.130
time: IE	−4.04 (1.34)	[-6.68; −1.41]	−3.01	0.003

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

Table 6
Multilevel poisson regression model predicting the 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	<0.001
time	−8.99 (5.05)	[-18.89; 0.92]	−1.78	0.075
NIC vs. EMDR	62.53 (29.58)	[4.48; 120.58]	2.11	0.035
NIC vs. ImRs	10.22 (29.54)	[-47.75; 68.18]	0.35	0.730
NIC vs. IE	46.73 (29.30)	[-10.76; 104.21]	1.60	0.111
time: EMDR	−29.00 (7.61)	[-43.93; −14.08]	−3.81	<0.001
time: ImRs	−11.45 (7.04)	[-25.27; 2.36]	−1.63	0.104
time: IE	−15.55 (7.08)	[-29.44; −1.67]	−2.20	0.028

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

6.1. Effects of Imagery Rescripting (ImRs)

We expected that ImRs would be associated with better memory recognition performance compared to EMDR and NIC, based on previous studies reporting improved memory accuracy following ImRs (Aleksic et al., 2024; Ganslmeier, 2022; Hagenaars & Arntz, 2012; Reineck et al., 2024; but see Ganslmeier et al., 2023). Contrary to this expectation, no significant differences in recognition performance emerged between ImRs and the other conditions.

A likely explanation for the lack of improvements is that the intervention may not have been potent enough to affect either voluntary (i.e., recognition performance) or involuntary memory (i.e., intrusions) as it did not reduce the number of intrusive memories, intrusion distress, or intrusion load compared to NIC.

Aside from this, differences in study design may also account for the discrepancy with prior findings. For instance, some of the previously reported beneficial effects of ImRs may have been partly driven by rehearsal effects: Some earlier studies employed highly standardized intervention protocols, involving extensive memory reactivation prior to the rescripting phase (e.g., Aleksic et al., 2024), and, in some cases, included additional rehearsal components, such as listening to audio recordings of the intervention between sessions (Ganslmeier et al., 2023). The absence of such components in the present study may help explain the discrepancy in findings.

Note that, while our findings do not support the hypothesis that ImRs *enhances* memory performance, they also offer no support for concerns that it *compromises* memory accuracy (e.g., Otgaar et al., 2021). While the overall null effects warrant cautious interpretation, it is notable that certain procedural features of ImRs – as implemented here –may have helped mitigate the risk of memory distortion, despite the intervention's reliance on counterfactual imagination.

One important factor concerns how counterfactual information is introduced. In misinformation studies, false information is typically presented subtly and without participants' awareness. In contrast, participants in the present study were explicitly informed that they would be imagining changes to their original memory – consistent with clinical ImRs protocols (e.g. Arntz & Weertman, 1999). Prior research suggests that warning individuals about the possibility of encountering misinformation can reduce the likelihood of memory distortion ("warning effect", e.g., Greene et al., 1982; Karanian et al., 2020). The transparent approach in ImRs may provide a similar protective effect.

Moreover, warnings appear especially effective when the altered details are easy to identify in a memory test, suggesting that the *salience* of memory alterations may also play a role (Neuschatz et al., 2003). In

ImRs, central aspects of the storyline are typically modified to address unmet needs and alter the emotional valence of the memory, while details that are not central or not experienced as distressing are usually left unchanged due to their limited clinical relevance. This was also evident in our study: participants primarily modified emotionally salient and distressing elements of the TSST scene, whereas more peripheral details remained largely unaltered.

Finally, although counterfactual imagining can lead to source monitoring errors – i.e., misattributing imagined events as real; Johnson et al., 1993; Thomas et al., 2003), – this risk is reduced when the imagined content is difficult to generate (Finke et al., 1988), when individuals are aware of the imagery process, and when the image is created intentionally (Foley et al., 2006). According to the source monitoring framework, the cognitive effort required to construct vivid mental imagery can serve as a cue for identifying it as internally generated (i.e., imagined) (Goff & Roediger, 1998; Henkel & Carbuto, 2008; Johnson et al., 1988). In the present study, participants not only intentionally generated alternative versions of the TSST scene but also engaged in complex cognitive operations to create these mental images (e.g., imagining new characters entering the scene, their appearance, voices, and behavior). This may have reduced the likelihood of memory errors.

6.2. Effects of Eye Movement Desensitization and Reprocessing (EMDR)

We hypothesized that EMDR would be associated with worse memory recognition performance compared to the other groups. This expectation was based on previous findings that eye movements performed during memory recall reduce memory vividness (Calvillo & Emami, 2019; Lee & Cuijpers, 2013; but see van Schie & Leer, 2019; see Kenchel et al., 2020 for a review of inconsistent findings), and that weaker memories are more prone to distortion (Loftus, 2005). Contrary to this prediction, EMDR did not impair memory recognition performance in the present study.

This finding contrasts with earlier research showing that eye movements can increase the likelihood of spontaneously generated false memories – i.e., distortions occurring in the absence of external misinformation – when memory is tested after a delay (e.g., Houben et al., 2020; Leer & Engelhard, 2020). A likely explanation for this discrepancy lies in methodological differences between our study and earlier research:

Studies reporting increased false memories typically used word lists (Houben et al., 2020) or paired photographs with aversive conditioning procedures (Leer & Engelhard, 2020) to induce memories. To more closely approximate the type of memories typically targeted in clinical contexts, we sought to elicit a more emotionally engaging and personally relevant memory by exposing healthy, but socially anxious, individuals to the TSST. Although the TSST did not evoke particularly high levels of distress in our sample, it required participants to actively engage in the task, likely increasing personal involvement and experiential immersion relative to the stimuli used in previous studies (see also Freund et al., 2025). This may have resulted in more personally meaningful memories that were less susceptible to distortion. Notably, this interpretation is also consistent with the findings by Meckling et al. (2024), who reported no changes in memory content when assessing the effects of eye movements on unpleasant autobiographical memories.

Another relevant difference may be the timing of the intervention. In prior studies, eye movements were often administered shortly after encoding, which may have interfered with initial memory consolidation (e.g., Houben et al., 2020, Exp.1; Leer & Engelhard, 2020). In contrast, our multiple-day design separated memory induction, intervention, and testing, in order to better approximate clinical practice, where EMDR typically targets consolidated memories. The absence of adverse memory effects in the present study may suggest that such consolidated memories are less prone to distortion through EMDR. However, timing alone may not fully explain the discrepancies between studies. Houben et al. (2020, Exp. 2), for instance, also introduced a delay between encoding and eye movements, yet found increased false memories, using the DRM paradigm. This suggests that both the timing of the intervention and the nature of the encoded material may be critical factors in determining whether eye movements impair memory performance.

Finally, unlike previous studies examining the effects of isolated eye movements, we administered additional components of the EMDR protocol. These included explaining the rationale for the intervention; 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 concluding with marking the new or alternative cognition and rating memory vividness. These elements may have strengthened the original memory through rehearsal while also sensitizing participants to potential changes in their memory - potentially producing a warning effect.

6.3. Effects of Imaginal Exposure (IE)

We expected IE to be associated with better memory recognition performance compared to EMDR and NIC. However, our findings did not support this assumption. While IE did not impair memory recognition, 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 rehearsal would improve memory performance (see Roediger & Butler, 2011), and previous studies had indeed reported improved memory performance following IE (Ganslmeier et al., 2023; Hagenaars & Arntz, 2012; Houben et al., 2018; Siegesleitner et al., 2019). While it is possible that the single session of IE may have been insufficient to produce memory enhancement, most prior studies reporting improved memory performance also used single and brief intervention sessions (e.g., Hagenaars & Arntz, 2012; but see Ganslmeier et al., 2023, who incorporated additional rehearsal by asking participants to listen to recordings of the intervention between sessions). Thus, session number alone may not fully account for the absence of effects in the current study.

The nature of the target memory may also have limited the potential for improvement. Although there was a one-week delay between memory induction and test, the memory of the TSST was still relatively recent. In addition, the use of the TSST was intended to increase personal relevance, which may have contributed to the formation of a relatively strong initial memory trace. However, it is important to note that recognition performance was moderate, suggesting that there was, in principle, room for further improvement through rehearsal. As our between-group design did not include pre-intervention assessments of memory recognition, we cannot determine whether recognition accuracy in the IE group increased, remained stable, or declined relative to each participant's baseline performance.

6.4. General discussion

Taken together, the findings of the present study do not indicate that EMDR, ImRs, or IE impair performance in a forced-choice memory recognition task. The observed reduction of intrusion distress and intrusion load in EMDR and IE, without adverse effects on memory accuracy, is consistent with the idea that voluntary and involuntary memories may 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 the TSST induced only a small number of intrusive memories initially 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 elicit enough intrusive memories to adequately assess intervention effectiveness.

Future studies should establish more clearly whether these interventions have robust dissociative effects on voluntary versus involuntary memory across different memory measures. For instance, Brewin's (2014) dual representation theory proposes 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.

7. Strengths and limitations

The present study has a number of important strengths. First, it is the first to directly compare the effects of EMDR, IE and ImRs on memory recognition performance. Second, we employed a multiple-day paradigm allowing us to assess intervention effects on consolidated memories, which are typically the target in clinical practice. Third, by using the TSST for memory induction, we were able to study autobiographical memory generated through direct personal involvement within a controlled setting – thereby approximating the type of memories typically targeted in clinical interventions, while maintaining experimental control over memory content. Fourth, we assessed the effects of EMDR using an adapted version of Shapiro's (2001) eight-phase protocol, rather than isolating the eye movement component, thereby providing a closer approximation to its clinical application. Finally, in line with previous studies from our group (Aleksic et al., 2024; Ganslmeier et al., 2022, 2023), the recognition items were designed to assess memory for content of practical relevance, including 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 examine intervention effects in a patient population or on real autobiographical or traumatic memories. 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 linked to increased susceptibility to false memories (see Loftus & Davis, 2006 for a review), clinical populations may be more susceptible to memory distortions than the population examined in the present study.

Moreover, the use of the TSST allowed us to induce an aversive autobiographical memory, while still maintaining experimental control over memory content, which was crucial for our study aims. However, it elicited only moderate distress and an insufficient number of intrusive memories. Although all interventions led to significant reductions in subjective distress from pre-to post-intervention – indicating that the TSST elicited an emotionally aversive memory and that the interventions effectively reduced the associated distress in the short term – the failure to induce a sufficient number of intrusive memories limited our ability to assess beneficial intervention effects. This contrasts with prior research demonstrating that the TSST can reliably evoke substantial distress and intrusive memories comparable to those induced by trauma film paradigms (e.g., Ganslmeier et al., 2023a). Future studies should clarify whether memory recognition performance would remain unimpaired when the interventions reduce these outcomes as intended. This question appears particularly relevant for ImRs, since we observed no reductions in either intrusion frequency, distress or intrusion load in this group, whereas EMDR and IE at least reduced intrusion distress and load. Thus, it remains uncertain how our findings would generalize to clinical settings and real-life emotional memories.

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, in the ImRs condition, we did not implement the full three-phase clinical protocol (i.e., reliving the memory as the child, intervening as the adult self, re-experiencing the memory from the child's perspective), as we worked with healthy participants and experimentally induced memories rather than childhood trauma. Although we included components associated with increased risk of memory distortion – such as imagery-based memory reactivation and memory modifications in ImRs – we cannot rule out the possibility that different outcomes would have emerged when using the full intervention protocol.

Fourth, as participants received half-standardized interventions, we had limited control over the contents generated during the intervention sessions. For example, in ImRs, participants decided individually how to exactly change the script to reduce distress. Similarly, in EMDR, participants identified their individual most distressing cognition and image and selected their preferred target cognitions. As a result, we were only able to assess one potential outcome - whether recognition performance at test differed between participants who have received an intervention and those in the no-intervention control group. However, our design did not allow us to determine whether any counterfactual content imagined during the interventions – either intentionally introduced as part of the rescripting phase in ImRs or spontaneously generated – was later falsely remembered as part of the original event. Future studies should address this by directly testing whether such details are later erroneously integrated into memory reports (e.g., Reineck et al., in prep.).

Relatedly, we did not implement formal treatment integrity checks to systematically assess whether interventions were delivered fully in line with the protocols. Although interventions were conducted by clinically trained experimenters under regular supervision, future studies should incorporate treatment integrity procedures to ensure standardized delivery across conditions and to rule out the possibility that null findings reflect limited intervention effectiveness.

Fifth, our assessment of memory accuracy relied solely on a memory recognition task. While this task offers a standardized way to evaluate memory for specific event details, it primarily measures participants' ability to recognize target information among distractors and thus captures only one facet of memory performance. It is unclear whether the recognition task was sensitive enough to detect potential differences between conditions. To address this limitation, future studies may consider incorporating alternative approaches. For instance, in eyewitness research, memory accuracy is often operationalized as the proportion of correctly recalled details relative to all possible details, and future studies may consider assessing this aspect as well. Moreover, because trauma survivors frequently need to provide detailed verbal accounts or identify offenders in line-ups during legal proceedings, including tasks – such as a cued recall, free recall or stimulus discrimination – may help improve both the informative value and external validity of findings. This is particularly important, as different memory tasks engage distinct cognitive processes and may yield divergent results. For example, studies using stimulus discrimination tasks have shown that eye movements can differently affect discrimination speed and accuracy (Leer et al., 2017; van den Hout et al., 2013). Similarly, findings from cued recall tasks sometimes diverge from those based on free recall (e.g., Malloggi et al., 2022). Although prior studies on ImRs have reported consistent results across recognition and free recall tasks (Ganslmeier et al., 2022, 2023), it remains unclear whether the current findings would generalize to other memory measures. Therefore, conclusions regarding memory accuracy in this study are limited to memory recognition performance.

Sixth, it should be noted that the criteria for proceeding to subsequent intervention phases differed between conditions. Specifically, in the EMDR condition, we allowed the installation phase to begin once subjective distress ratings had decreased to a level of ≤ 2 on the SUD scale, whereas in the IE condition, we required a reduction to ≤ 1. This decision was based on clinical considerations and reflects common practice in EMDR, where proceeding with the installation phase is often considered appropriate when distress plateaus at a low level. Although this difference in termination criteria may have influenced the degree of residual distress at the end of the intervention, potentially affecting intervention efficacy and memory outcomes, it is important to note that EMDR still produced a significant reduction in subjective distress from pre-to post-intervention, which was greater than the reduction observed in the IE condition. Nevertheless, future studies should consider harmonizing cutoff thresholds across conditions to improve comparability.

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).

8. Implications

Concerns that trauma-focused treatments might compromise memory can create a dilemma for trauma survivors: while they may need psychological treatment to cope with trauma-related disorders, they may also worry that undertaking treatment might later jeopardize their credibility as witnesses in court (Bublitz, 2020). Against this background, understanding whether interventions such as EMDR, ImRs, and IE compromise memory is highly relevant for both clinical and forensic practice.

When testing experimentally induced memories of an event that participants actively took part in (the TSST), we observed no detrimental intervention effects on performance in a forced-choice recognition task. For ImRs and IE, the present findings are consistent with prior laboratory studies that have so far found no evidence of impaired recognition of experimentally induced memories in healthy samples (Aleksic et al., 2024; Ganslmeier et al., 2022, 2023). For EMDR, by contrast, prior studies reported negative effects of eye movements as employed in EMDR when other memory tasks (e.g., free recall, perceptual stimulus discrimination, yes/no recognition) and different materials for memory induction (e.g., film clips, word lists) were used (Houben et al., 2020; Leer & Engelhard, 2020). This highlights the need to better understand the specific conditions under which detrimental effects are likely to occur (e.g., task formats and cognitive processes required, intervention instructions, population characteristics, type of memory examined). Future research should systematically compare outcomes across different paradigms and populations, and also examine how the present findings extend to tasks more central to credibility assessments, such as consistency across repeated free narrative recall.

Beyond the intrinsic risks that trauma-focused interventions may carry when applied lege artis, it is also essential to consider the risks associated with their misuse. Recent evidence suggests that a notable proportion of EMDR therapists employ suggestive techniques aimed at "recovering repressed memories" (Schemmel et al., 2024). Such practices can turn psychological treatment into a problematic setting, for instance when history of trauma is inferred from observed symptoms and therapists actively search for repressed memories, even if there was no prior recollection of trauma. Susceptibility to such influences is heightened when individuals are uncertain about their own memories (Gabbert et al., 2003) or when misinformation originates from a trusted authority figure (Pena et al., 2017). Patients with memory gaps or those seeking explanations for their distress may therefore be particularly vulnerable. Importantly, these risks are not confined to therapeutic contexts but may also arise in interactions with police, lawyers, or even family members. Understanding how external suggestion interacts with trauma-focused interventions thus represents an important line of research in its own right.

9. Conclusion

By directly comparing the effects of EMDR, IE, and ImRs within the same experimental framework, this study contributes to the debate on whether trauma-focused psychological interventions compromise the factual accuracy of memories targeted in treatment. In a laboratory setting with healthy participants, none of the interventions impaired forced-choice recognition of experimentally induced aversive memories when assessed after a time delay. Considered together with prior research, the findings suggest that intervention effects may vary depending on the type of memory assessed and the memory task employed. Future research should aim to disentangle the mechanisms driving these task- and memory-specific effects, specify the conditions under which trauma-focused interventions may – or may not – pose a risk of memory distortion, and clarify how such experimental findings translate to both clinical and forensic settings. This could inform clinical training and treatment guidelines and sensitize both clinicians and legal professionals to potential risk constellations.

CRediT authorship contribution statement

Milena Aleksic: Writing – review & editing, Writing – original draft, Visualization, Software, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Thomas Ehring:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Anna Kunze:** Writing – review & editing, Supervision, Methodology, Funding acquisition, Conceptualization. **Larissa Wolkenstein:** Writing – review & editing, Supervision, Methodology, Conceptualization.

Preregistration

The hypotheses, study design and analysis plan of this study were preregistered at the Open Science Framework (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.

Open practices and data sharing

All data, codes and materials have been made publicly available via the Open Science Framework and can be accessed at https://osf.io/h3c7w/

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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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.brat.2025.104884.

Data availability

Anonymized data, codes and materials have been made publicly available via the Open Science Framework and can be accessed at https://osf.io/h3c7w/. We referred to the link in the manuscript.

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