Behaviour Research and Therapy 170 (2023) 104409

Contents lists available at ScienceDirect

Behaviour Research and Therapy

journal homepage: www.elsevier.com/locate/brat

Effects of imagery rescripting and imaginal exposure on voluntary memory

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A R T I C L E I N F O

Keywords:
Post-traumatic stress disorder
Declarative memory
Voluntary memory
Imagery rescripting
Imaginal exposure
Trauma film

A B S T R A C T

Trauma-focused imagery-based interventions, such as Imagery Rescripting (ImRs) and Imaginal Exposure (ImE), are effective in reducing involuntary re-experiencing in PTSD. However, it has been suggested that they may impair voluntary memory. This study investigates whether ImRs and ImE distort voluntary memory of an analogue trauma. We presented a trauma film to $N = 120$ healthy participants (Session 1) and randomly allocated them to one of two intervention conditions (receiving one session of ImRs or ImE) or to a no-intervention control condition (NIC) afterwards (Session 2). Voluntary memory was assessed using a free recall (Sessions 2 and 3), and a cued recall as well as a recognition task (both Sessions 3 and 4). The ImRs and ImE groups did not differ from NIC in the cued recall task and the recognition task. However, ImE (compared to ImRs and NIC) led to an increase in correct reported details in the free recall. In sum, the current findings do not suggest that ImRs or ImE impair voluntary memory.

1. Introduction

Negative memories are at the core of post-traumatic stress disorder (PTSD). Accordingly, it has been conceptualized as a *disorder of memory*. Visser et al. (2018), for example, classify three relevant memory systems involved in trauma-related alterations: First, the *declarative involuntary* memory system that is characterized by unwanted, emotionally aversive memories that come to mind unprompted in the form of sensory imagery. This resembles one of the core symptoms of PTSD – namely, involuntary re-experiencing of the traumatic event in the form of intrusive memories, flashbacks, or nightmares. Second, the *non-declarative involuntary* memory system refers to automatic psychophysiological responses that are typically triggered by trauma-related cues but can also occur spontaneously. This reflects characteristic PTSD symptoms such as elevated physiological reactions to trauma-related cues, hyperarousal, and hypervigilance. The third memory system is the *declarative voluntary* memory system which comprises intentionally recalled episodes and facts when choosing to report the trauma.

Given the burden caused by both declarative and non-declarative *involuntary* memory aspects, it is not surprising that clinical interventions mainly target these processes aiming at reducing the frequency and severity of involuntary memory symptoms. At the same time, it appears important that treatment preserves *voluntary* attempts to recall the trauma. These aspects can be of critical importance not only to prevent revictimization but also for legal reports and testimony (e.g., in the context of civil or social claims or criminal proceedings against offenders) often associated with man-made trauma (Herman, 2003; Lau-Zhu et al., 2019).

The method of choice for the treatment of PTSD, namely trauma-focused cognitive behavioral therapy (TF-CBT) which often includes Imaginal Exposure (ImE) or – in recent times – Imagery Rescripting (ImRs), has repeatedly been shown to be effective in targeting PTSD symptoms; in particular, it effectively reduces involuntary re-experiencing of emotional aversive memories (Courtois et al., 2017; Cusack et al., 2016; Morina et al., 2017; Weber et al., 2021). The effect of trauma-focused treatment on PTSD symptomatology has been shown in controlled trials with clinical samples (e.g., Arntz et al., 2007; Langkaas et al., 2017) and in analogue studies including healthy individuals (e.g., Hagenaars & Arntz, 2012; Rijkeboer et al., 2020; Strohm et al., 2019). However, while we can conclude that TF-CBT has the desired effect on involuntary memory aspects, the effect of TF-CBT on voluntary memory aspects has rarely been investigated in the past. Given that certain psychological interventions are suspected of distorting voluntary memory (Brainerd & Reyna, 2005; Ridley et al., 2012), this is rather surprising. Even more so, as this assumption has a huge impact on people who suffer from PTSD and need psychological treatment; police and lawyers even advise against psychological treatment before the conclusion of criminal proceedings (Bublitz, 2020; Wolf & Werner, 2021) because survivors' testimony may lose probative value in court when TF-CBT has already taken place.

Hence, although there is broad agreement that psychological

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https://doi.org/10.1016/j.brat.2023.104409
Received 1 July 2023; Received in revised form 19 September 2023; Accepted 1 October 2023
Available online 10 October 2023

treatment for PTSD should aim to reduce involuntary intrusive memories, while leaving voluntary trauma memory unchanged (Holmes et al., 2010; Visser et al., 2018), it remains unclear whether TF-CBT really has this selective effect on different trauma memory systems. From a basic memory perspective (e.g., Visser et al., 2018) it appears possible to selectively influence the voluntary and involuntary memory systems in the treatment of PTSD as they are mostly supplied by different brain regions (Squire, 2004). Furthermore, it has been shown that voluntary vs. involuntary memory can be independently targeted with experimental interventions (James et al., 2015; Soeter & Kindt, 2010) or can be selectively damaged (Adolphs et al., 2005; Weike et al., 2005).

These general assumptions regarding a differential impact of interventions on different memory systems are also in line with specific theories on information-processing in PTSD (Dalgleish, 2004), such as the (revised) Dual Representation Theory (Brewin et al., 1996, 2010). This theory – a separate-trace model – assumes that two types of memory representations are encoded during a traumatic event: (1) a contextual representation (C-reps) that includes voluntary accessible aspects of the traumatic event and (2) a sensory and emotion-laden representation (S-rep) of the traumatic event that can only be accessed involuntarily. It is hypothesized that involuntary aspects of trauma memories (unlike non-traumatic memories) are not sufficiently contextualized within autobiographical memory, i.e., intrusive memories arise from poor associations of C-reps and S-reps (Brewin, 2014). According to this view, effective TF-CBT includes retrieving both C-reps and S-reps and may thus facilitate the integration of both and lead to a more elaborated and contextualized representation (Brewin, 2014). This possibly leads to better control of involuntary memory and higher voluntary accessibility of aspects of the trauma memory, which in sum is assumed to increase memory quality. Since both ImRs and ImE involve repeated rehearsal and retrieval of contextualized and sensory-bound representations, both interventions are likely to support this integration process. However, since ImRs (depending on how early or late the hotspot is) does not focus on the complete memory trace, this might be less pronounced here compared to ImE, where the complete memory is repeatedly processed.

A look at the results of experimental psychopathology strengthens the assumption that psychological interventions could indeed have the desired selective effect on involuntary and voluntary aspects of trauma memory. Analogue studies used the trauma film paradigm (Holmes & Bourne, 2008) to investigate the effects of ImRs or ImE on involuntary and voluntary memory as compared to an active (i.e., positive imagery of a personal, pleasant experience) (Hagenaars & Arntz, 2012) or a no-intervention control group (NIC) (Siegesleitner et al., 2019). To assess voluntary memory a cued recall task was used. While both ImRs and ImE reduced the occurrence of intrusive memories (Hagenaars & Arntz, 2012; Siegesleitner et al., 2019), they left voluntary memory intact (Siegesleitner et al., 2019) or even improved it (Hagenaars & Arntz, 2012). However, interpretation of findings from these studies is complicated by the fact that (1) they looked at voluntary memory only as a secondary outcome, (2) effects of trauma-focused interventions on voluntary memory was only assessed in an exploratory way, and (3) studies used only a small number of cued recall items to assess voluntary memory. Therefore, Ganslmeier et al. (2022) conducted a more detailed follow-up analogue study directly investigating the effect of ImRs on voluntary memory. In line with the earlier analogue studies described above, the authors found an *improvement* in voluntary recall after ImRs whereas the number of intrusive memories did not differ between ImRs and a NIC.

The first study investigating the influence of ImRs and ImE (compared to supportive counseling) on both involuntary and voluntary memory aspects in a clinical sample was carried out by Romano et al. (2020). The authors used a free recall task to measure the amount of remembered positive, neutral, and negative details of an autobiographical memory in a sample with social anxiety disorder. Involuntary aspects like intrusiveness, vividness, and negative affectivity associated with the memory decreased following both ImRs and ImE. In contrast, voluntary memory details reported *increased* after the imagery-based interventions but not in the supportive counseling group. Interestingly, while the number of positive, neutral as well as negative memory details increased after ImE, only the number of positive and neutral details increased after ImRs. These results suggest that primarily those aspects were reported in more detail following the interventions that were focused on in the interventions. That is, while ImE equally focuses on all kinds of memory details, ImRs purposefully changes negative memory aspects. This might cause difficulties remembering specifically negative memory aspects while improving positive aspects. However, Romano et al. (2020) did not examine whether the changes caused by ImRs and ImE reflected an influence on the accuracy of the memory. That is, the memory details that were added after the interventions could also be misremembered or incorrectly added details. To investigate to what extent ImRs and ImE change voluntary memory and to deal with the limitations of prior studies we adapted the methodology for this study as follows: First, we used the trauma film paradigm to induce a standardized but aversive experience. This has not only proven to effectively induce analogue PTSD symptoms (James et al., 2016), but also allows conclusions to be made about intervention effects on memory accuracy. Second, we used a multi-day set-up to extend the interval between analogue trauma and intervention such that there is enough time for consolidation. Third, voluntary memory was assessed more comprehensively than in earlier research by using a cued recall (with a greater number of items), a free recall assessing correct and incorrect details and a visual recognition task.

Based on the theoretical ideas of the separate-trace theories and earlier empirical findings, we hypothesized that ImRs and ImE (compared to NIC) would result in more details being remembered correctly and less details being remembered incorrectly.

2. Method

2.1. Overview

The overall procedure included an online screening for trait anxiety (Session 0) and four study sessions (see Fig. 1). One day after having watched the trauma film (Session 1) participants completed the free recall and received the intervention (ImRs vs. ImE vs. NIC) (Session 2). Six days later, voluntary memory was measured by a second free recall, a first cued recall and a first recognition task (Session 3). Another week later, the cued recall and the recognition task were repeated (Session 4).

To prevent carryover effects between tasks, cued recall and recognition task were only introduced after the two free recall tasks had been completed. While the first three sessions were conducted in the laboratory, Session 4 consisted of a web-based questionnaire; via e-mail, participants received a link to complete an online questionnaire (using the survey software *Unipark*). Since Session 4 was collected in online mode, a free recall was not conducted.

2.2. Participants

Participants were recruited via a student email newsletter, advertisement in social media, and posters put up at university buildings. Since the film fragment showed the rape of a woman and women and men may process this differently, we included only female participants to rule out gender effects. We included female students who met the following inclusion criteria: (1) age between 18 and 30 years, and (2) fluency in German. In addition, the following exclusion criteria were applied: (1) current mental disorder or life-time PTSD, bipolar or psychotic disorders (German adaptation of the Structured Clinical Interview for DSM-5 Disorders [SCID-5]; Beesdo-Baum et al., 2019) or severe neurological disorder, (2) life-time experiences of sexual or physical violence (German version of the Life Events Checklist for DSM-5 [LEC-5]; Krüger-Gottschalk et al., 2017) (3) current psychological treatment, (4) current pregnancy (5) use of psychiatric medication, (6)

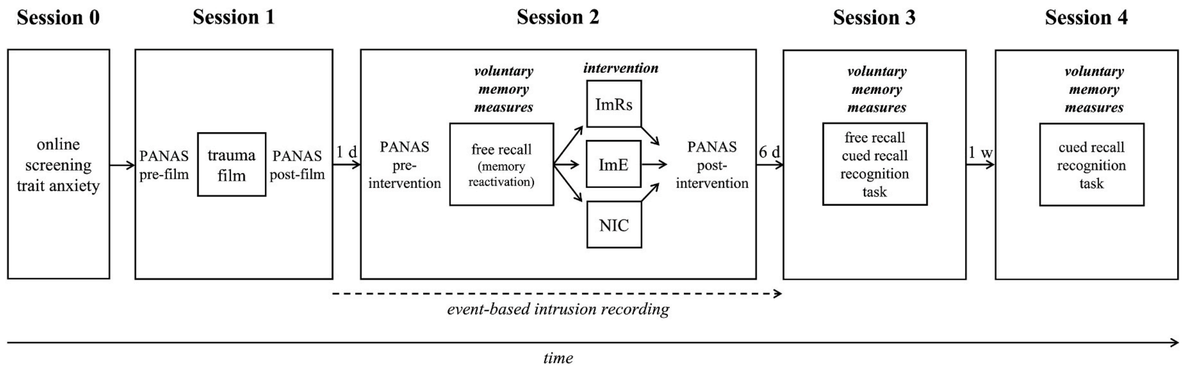

Fig. 1. Experimental Procedure
Note. PANAS Positive and Negative Affect Schedule (Krohne et al., 1996), *ImRs* participants received imagery rescripting as an intervention, *ImE* participants received imaginal exposure as an intervention, *NIC* participants waited 15 min in front of the laboratory.

consumption of illegal drugs within the last three days, or (7) alcohol consumption of more than three glasses of beer, wine, cocktails or hard liquor within the last 24 h before the experiment. In terms of generalizability to reactions to traumatic events and external validity, we wanted to include individuals who had stronger emotional reactions to the film and experienced more intrusive memories. Since low baseline measures of trait anxiety are associated with the absence of analogue flashbacks (Clark et al., 2015), a total of 860 students were screened online via the survey software *Unipark* for trait anxiety (German Trait Scale of the State-Trait Anxiety Inventory [STAI-T]; Laux et al., 1981). Of these 860 students, only participants with high trait anxiety (cut-off: score >39) were invited to participate in further investigation in the laboratory (Wiglusz et al., 2019). A total of 155 participants met this cut-off criterion and were invited to the laboratory. Twenty-seven participants had to be excluded based on inclusion or exclusion criteria. In addition, four participants dropped out due to corona restrictions (i.e., one or two measurement time points had already taken place, the following ones then had to be cancelled due to the lockdown), and two participants withdrew their consent after Session 1. Due to technical problems, data from two participants were lost. Thus, the final sample size was $N = 120$ (age: $M = 22.24$, $SD = 2.85$). Participants were randomly allocated to one of three experimental conditions: ImRs ($n = 40$), ImE ($n = 40$) or no-intervention control (NIC) ($n = 40$).

For sample size planning, an a priori power analysis was carried out with *G*Power* (Faul et al., 2009). Based on prior research (e.g., Ganslmeier et al., 2022; Garry et al., 1996; Horselenberg et al., 2000), we assumed the effect of imagery on voluntary memory to be of medium size ($f = 0.25$). With $\alpha = 0.05$ and a statistical power of .80, it was necessary to recruit 42 participants to detect a Condition × Time interaction, 120 participants to detect a main effect of Condition and 36 participants to detect a main effect of Time on voluntary memory as measured by recognition task, free and cued recall (3 [Condition] × 2 [Time] ANOVAs).

Participants signed a written informed consent and were provided compensation of either € 8 per hour or course credits. The study was approved by the local Research Ethics Committee (2019_36_Ganslmeier_c).

2.3. Materials

2.3.1. Trauma film

During Session 1, participants watched a 14-min fragment of *Irréversible* (Noé, 2002) showing sexual and physical abuse of a woman. This is a useful method to induce analogue post-traumatic stress symptoms such as intrusive memories, negative emotions, and subjective distress (Arnaudova & Hagenaars, 2017). All participants were explicitly informed in the study information and informed consent that they would be shown a film with violent content. The film was shown on an 18-inch screen in a darkened room. Before the film started, participants were instructed to imagine they would witness the situation shown in the film scene at that very moment.

2.4. Intervention

2.4.1. Imagery rescripting (ImRs)

ImRs usually involves memory reactivation first. For this, we used free recall (see Measures section) to initiate the reconsolidation process (detailed instructions are provided in Supplementary Material A). This was followed by the actual ImRs using a modified script according to Arntz and Weertman (1999) (detailed instructions are provided in Supplementary Material B):

Participants were instructed to reactivate the scene from the beginning of the film fragment to just before the rape (standardized hotspot) and to imagine this as vividly as possible with their eyes closed. They were asked to describe the scene in the present tense and in the first-person singular with all sensory, emotional, and physical sensations occurring.

Once participants reached the hotspot, the investigator instructed them to change the script in their imagination to achieve an outcome of the scene that was less stressful for them. For this purpose, the investigator suggested participants to imagine two men entering the scene and coming to the victim's aid before the perpetrator begins to rape her. Participants were then asked to imagine how the two men were confronting the perpetrator. Once the perpetrator was disempowered, the investigator instructed participants to imagine that the perpetrator is arrested by two police officers and that there is no more danger from him. At the end, participants were instructed to imagine the woman being cared for until she feels safe. During the imagination, the investigator asked in-depth questions, e.g., about the place, people present, sensory perceptions, thoughts, and bodily sensations. Once participants indicated that they were completely satisfied with the outcome of the situation, ImRs was concluded (duration [minutes]: $M = 21.28$, $SD = 5.23$).

ImRs was tape-recorded and participants were instructed to listen to the recording three times before Session 3 (Smucker et al., 1995).

2.4.2. Imaginal exposure (ImE)

As with ImRs, ImE was preceded by free recall. This was followed by ImE using a modified script based on Foa et al. (2008) (detailed instructions are provided in Supplementary Material B): Participants were instructed to reactivate the scene from the beginning of the film fragment through the hotspot to the end of the scene and to imagine the whole scene as vividly as possible with their eyes closed. As with ImRs, they were asked to report in the present tense, first person singular, and to include all sensory, emotional, and physical sensations. The investigator also asked questions to deepen the imagination. Once participants reached the end of the scene in the imagination, ImE was completed (duration [minutes]: $M = 15.88$, $SD = 4.39$).

ImE was also tape-recorded, and participants were instructed to listen to it three times before Session 3.

2.4.3. No-intervention control condition (NIC)

Participants of the control condition received neither ImRs nor ImE and instead had a 15-min break, in which they sat outside the laboratory room.

2.5. Measures

2.5.1. Voluntary memory measures

Voluntary memory was assessed in three ways: with a free recall in order to assess memory in a broad, complex and individual manner and with a cued recall and a recognition task to assess concrete and specific details and images.

2.5.1.1. Free recall. Two free recalls (Session 2 and Session 3) were used to assess possible changes in voluntary memory of the aversive film scene after ImRs or ImE. Using a standardized script (for detailed instruction, see Supplementary Material A), participants were instructed to imagine their experience of the situation of the aversive film scene as a witness at that moment and to verbally report everything they remembered of the film scene as accurately and in as much detail as possible. As in ImRs and ImE, they were asked to close their eyes and to describe their experience in the first person singular and in present tense as if they were experiencing it in this very moment. According to the instruction, they were to describe the scene until they themselves decided that the scene was complete (duration [minutes]: Session 2: $M = 8.76$, $SD = 4.08$; Session 3: $M = 8.03$, $SD = 3.41$). The report was tape-recorded, transcribed, and coded to enable us to analyze changes in voluntary memory using a standardized protocol-based assessment adapted from Levine et al. (2002) and Jack et al. (2014) (for detailed instruction, see Supplementary Material C).

For this purpose, each free recall was divided into information details defined as a unique event, observation, or thought, usually expressed as a grammatical clause (i.e., subject and verb) (adapted from Levine et al., 2002). Further information clauses (i.e., object, adverbs, adjectives, etc.) were additionally scored. Furthermore, all details that were specific to time and place of the trauma film fragment (reflecting episodic reexperiencing) (vs. not specific to time and place, semantic knowledge, repetitions, other details, retrospective appraisals) were rated as *correct* (if they represented details that had been present during the trauma film fragment) or *incorrect* (if they represented details that had *not* been present) (adapted from Jack et al., 2014). All other details with unclear validity were categorized as *possible*. Since thoughts and emotions cannot be evaluated for correctness, they were not rated here.

Based on the ratings, sum scores were computed for (a) number of correct details, (b) number of incorrect details, and (c) total number of details provided (to control for the overall verbal output). The ratings were conducted by two independent raters. Based on criteria suggested by Koo and Li (2016) interrater reliability, measured by intraclass correlations (ICC), was excellent for ICC_{total} (1, 1) = 0.98 and $ICC_{correct\ details}$ (1, 1) = 0.95. It was good for $ICC_{possible\ details}$ (1, 1) = 0.77 and $ICC_{incorrect\ details}$ (1, 1) = 0.87.

2.5.1.2. Cued recall. In Sessions 3 and 4, participants completed a cued recall which was inspired by a police interrogation guide (Hermanutz & Schröder, 2015). It included questions about the location, the acting persons, and the procedure. The cued recall comprised a total of 32 questions (for the detailed cued recall, see Supplementary Material D).

2.5.1.3. Recognition task. During Session 3 and Session 4, participants were shown a series of images from the aversive film. Some of the images were actually taken from the film fragment the participants had seen, and some were from sections of the film not shown in the study. For each image, participants were asked to indicate whether they had seen it in the film scene presented during Session 1.

2.5.2. Manipulation check

2.5.2.1. Effect of the trauma film and the intervention on participants' mood. To assess how aversive participants had experienced the film fragment, the Positive and Negative Affect Schedule (PANAS; German version: Krohne et al., 1996) was filled in immediately pre- and post-film. In addition, participants answered the PANAS before and after the intervention to measure intervention effects on mood. The PANAS consists of two scales (positive and negative affect) with ten items each and asks participants to rate their current affective states on a 5-point Likert scale (1 = *not at all*; 5 = *extremely*). Sum scores were calculated for each scale and measurement time.[1]

2.5.2.2. Intrusion measures. Adapted from paper tabular intrusion diaries used in earlier research (James et al., 2015), trauma film-related intrusive memories between Session 1 and Session 3 were assessed using the experience sampling app *tellmi*.[2] The application was installed on participants' smartphones at the end of Session 1. If a participant did not possess a smartphone, they were lent one by the experimenter. Participants were instructed to register an intrusive memory directly in the app every time they experienced one in their daily lives (event-based assessment). Every time they registered an intrusive memory, they were asked how stressful, controllable, and vivid they had experienced it (1 = *not at all* to 6 = *very much*).[3]

2.5.3. Control variables

We assessed trait anxiety using the German version of the STAI-T and suggestibility using a German translation of the Multidimensional Iowa Suggestibility Scale (MISS; Kotov et al., 2004) (see Table 1).

In addition, sleep duration and quality after Session 1 and 2 and in the week between Session 2 and 3 was surveyed. Participants were also asked whether they had known the film before study participation, whether they frequently watched films with similar violent content, and whether they had gone through the trauma film repeatedly by talking to others or writing a diary (*yes* vs. *no*).

2.6. Procedure

Session 0 Interested participants completed the STAI-T online via *Unipark*. Only participants with a score above the cut-off were selected for further screening and could contact the experimenter to make an appointment.

[1] Internal consistencies were good or excellent for both positive (pre-film: $\alpha = 0.85$; post-film: $\alpha = 0.85$; pre-intervention: $\alpha = 0.89$; post-intervention: $\alpha = 0.84$) and negative affect (pre-film: $\alpha = 0.80$; post-film: $\alpha = 0.92$; pre-intervention: $\alpha = 0.82$; post-intervention: $\alpha = 0.88$).

[2] See Acknowledgements.

[3] In addition, and as a back-up, in the case that the app would fail, participants were asked in each session to indicate how often they had experienced intrusive memories since the last session, the percentage of time (from 0 to 100) they had experienced them and – in case they reported at least one intrusive memory – how stressfully, controllably, and vividly they experienced them (0 = *not at all* to 100 = *very much*). Since the results do not differ with respect to their significance, only the ecologically more valid variant (i.e., event-based intrusive memories recording) is reported below. However, the descriptive statistics can be viewed in Supplementary Material E.

Table 1
Sociodemographic and control variables.

Variables	Condition			Statistics	*p*
	ImRs ($n = 40$)	ImE ($n = 40$)	NIC ($n = 40$)		
Sociodemographic variables	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)		
Age [a]	22.62 (2.90)	21.85 (2.58)	22.25 (3.08)	$F(2, 116) = .71$	.49
Number of years of education [a,b]	15.35 (2.48)	15.40 (2.54)	15.42 (2.71)	$F(2, 115) = .01$	.99
Control variables	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)		
Trait anxiety (STAI-T)	46.00 (7.55)	47.60 (7.03)	47.33 (7.79)	$F(2, 117) = .53$	.59
Suggestibility (MISS) [a]	176.59 (29.13)	175.93 (23.25)	182.05 (23.05)	$F(2, 116) = .71$	.50
Sleep at night after Session 1: sleep duration (in hours)	7.35 (1.38)	7.23 (1.22)	7.83 (0.98)	$F(2, 117) = 2.77$	.07
Sleep at night after Session 1: sleep quality	2.13 (0.69)	2.05 (0.68)	1.83 (0.50)	$F(2, 117) = 2.48$	.09
Sleep at night after Session 2: sleep duration (in hours) [a]	7.35 (0.81)	7.38 (1.47)	7.64 (1.03)	$F(2, 116) = .79$	.46
Sleep at night after Session 2: sleep quality	2.08 (0.53)	2.08 (0.62)	2.08 (0.42)	$F(2, 117) = .00$	1.00
Sleep between Session 2 and 3: sleep duration	7.23 (0.83)	7.36 (0.98)	7.49 (0.81)	$F(2, 117) = .90$	.41
Sleep between Session 2 and 3: sleep quality	2.10 (0.55)	2.15 (0.58)	2.10 (0.50)	$F(2, 117) = .11$	.89
	%	%	%		
Knew the film scene shown (no)	95.0	92.5	95.0		.90 [c]
Frequent watching of films with similar violent content (no)	57.5	57.5	52.5		.93 [c]
Talked to sb. about the trauma film in the week after (yes)	77.5	65.0	65.0	χ^2 (1) = 1.95	.42
Wrote diary about the trauma film in the week after (no)	90.0	85.0	90.0		.95 [c]

Note. *ImRs* imagery rescripting, *ImE* imaginal exposure, *NIC* no-intervention control, *STAI-T* Trait Scale of the State-Trait Anxiety Inventory.
[a] ImRs ($n = 39$).
[b] NIC ($n = 39$).
[c] Fisher's exact test.

Session 1 After participants having provided written informed consent and after inclusion as well as exclusion criteria had been checked, sociodemographic and control variables were collected from all eligible participants. This was followed by the PANAS pre-film, the trauma film fragment, and the PANAS post-film.[4] At the end, participants were instructed to install the app *tellmi.*

Session 2 After participants had been randomly assigned to one of three conditions (ImRs vs. ImE vs. NIC), sleep quality and duration were collected. This was followed by PANAS pre-intervention and the first free recall. Participants then underwent the intervention (ImRs or ImE) or a short break (no intervention). This was followed by the PANAS post-intervention and, in the ImRs and ImE condition, the instruction to listen to the tape recording of the intervention three times before Session 3.

Session 3 As in Session 2, sleep quality and duration, and free recall were collected. Then the cued recall and recognition task were performed for the first time. In addition, participants were asked whether they had talked to others about the aversive film or had written a diary.

Session 4 Participants received a link via e-mail to answer an online questionnaire at home. Again, cued recall, and recognition task were administered. A debriefing followed at the end, informing about the purpose and objectives of the study, and including a contact address in case of persistent distress due to the film.

The experimenter for Session 1 and Session 3 as well as participants were all blind to the intervention condition.

2.7. Statistical analyses

Data analyses were conducted using SPSS (IBM SPSS Statistics, version 29). All hypotheses were tested two-sided with a significance level of $\alpha = 0.05$.

Potential differences between experimental conditions regarding sociodemographic and control variables were examined with one-way independent ANOVA and chi-square tests.

We calculated mixed 3 (Condition) × 2 (Time) ANOVAs to assess the effect of the trauma film and the interventions, respectively, on participants' mood. Condition differences regarding intrusive memories were examined with MANOVA.

Lastly, mixed 3 (Condition) × 2 (Time) ANOVAs were used to assess the effect of the interventions on participants' free recall, cued recall, and recognition task.

Assumptions for parametric tests were examined. Given that ANOVAs are considered robust to violations of normal distribution assumptions (Harwell et al., 1992) and are less sensitive to variance heterogeneity (Field, 2013) when group sizes are approximately equal, ANOVAs were still used even when normality and variance homogeneity assumptions were violated.

3. Results

3.1. Baseline differences in control variables

The three conditions did not differ regarding any of the sociodemographic or control variables (see Table 1).

3.2. Manipulation check

3.2.1. Trauma film

Trauma film increased negative affect and reduced positive affect. Descriptive statistics of the PANAS pre-film and post-film are presented in the Supplementary Material (see Supplementary Material E, Table S4).

To check whether the trauma film was experienced as stressful for

[4] Additionally, participants completed the German version of the Beck Depression Inventory II (BDI II; Hautzinger et al., 2009), Questionnaire for the Assessment of Disgust Responsiveness (FEE; Schienle et al., 2002), Scale for Assessing Disgust Sensitivity (SEE; Schienle et al., 2010), German translation of the Gudjonsson Suggestibility Scale (GSS; Gubi-Kelm & Schmidt, 2018), Stress Appraisal Measure (SAM; Delahaye et al., 2015), Multidimensional Mood Questionnaire (MMQ; Steyer et al., 1997) and Heidelberg Form for Emotion Regulation Strategies (HFERST; Izadpanah et al., 2019) in Session 1. HFERST was repeated in Session 2, Session 3 and Session 4. SAM and MMQ were repeated in Session 3 and Session 4. Due to the non-relevance of these questionnaires to the current research question, the results are reported elsewhere, and these measures are not further addressed in this manuscript for the sake of clarity.

participants, two mixed 3 (Condition: ImRs vs. ImE vs. NIC) × 2 (Time: pre-film vs. post-film) ANOVAs were performed. There was a main effect of Time showing that the negative affect was significantly higher post-film than pre-film, $F(1, 116) = 267.90$, $p < .001$, $\eta_p^2 = .70$. However, neither a main effect of Condition, $F(2, 116) = 0.80$, $p = .45$, $\eta_p^2 = .01$, nor a Condition × Time interaction emerged, $F(2, 116) = 2.02$, $p = .12$, $\eta_p^2 = .04$.

There was a main effect of Time showing that the positive affect was significantly lower post-film than pre-film, $F(1, 116) = 187.19$, $p < .001$, $\eta_p^2 = .62$, but no main effect of Condition, $F(2, 116) = 1.15$, $p = .32$, $\eta_p^2 = .02$, and no Condition × Time interaction, $F(2, 116) = 0.32$, $p = .73$, $\eta_p^2 = .01$.

The trauma film successfully triggered intrusive memories. Descriptive statistics of the intrusion measures (between Session 1 and Session 3) were calculated and are presented in the Supplementary Material (see Supplementary Material E, Table S5). In a MANOVA using Pillai's trace, there was no significant main effect of Condition on intrusion measures, $V = 0.06$, $F(8, 184) = 0.67$, $p = .71$, $\eta_p^2 = .03$. As a back-up in the case of a failure of the app, we retrospectively collected intrusion measures at each of the measurement points. Again, it is found that the trauma film successfully triggered intrusive memories whose distress and vividness decreased over time and whose controllability increased over time. Yet again, there were no significant differences between the groups. Descriptive statistics are reported in the Supplementary Material (see Supplementary Material E, Table S6).

3.2.2. Intervention

To check whether the intervention had an impact on participants' positive and negative affect, two mixed 3 (Condition: ImRs vs. ImE vs. NIC) × 2 (Time: pre-intervention vs. post-intervention) ANOVAs were performed. Intervention increased negative and reduced positive affect. Descriptive statistics are presented in Table 2.

There was a main effect of Time showing that negative affect was significantly higher post-intervention than pre-intervention, $F(1, 117) = 202.91$, $p < .001$, $\eta_p^2 = .63$. In addition, there was a Condition × Time interaction, $F(2, 117) = 10.19$, $p < .001$, $\eta_p^2 = .15$, indicating that negative affect increased less in NIC than in the ImRs and ImE. However, no significant main effect of Condition emerged, $F(2, 117) = 1.61$, $p = .20$, $\eta_p^2 = .03$.

In addition, a significant main effect of Time was found showing that positive affect was significantly lower post-intervention than pre-intervention, $F(1, 117) = 56.21$, $p < .001$, $\eta_p^2 = .33$. Additionally, there was a significant main effect of Condition, $F(2, 117) = 6.29$, $p = .003$, $\eta_p^2 = .10$. Bonferroni-adjusted post-hoc analysis revealed that positive affect was significantly lower in the ImE than in the ImRs ($p = .002$), with no differences between ImRs and NIC ($p = .11$) or ImE and NIC ($p = .50$). The Condition × Time interaction was not significant, $F(2, 117) = 0.08$, $p = .92$, $\eta_p^2 = .00$.

3.3. Voluntary memory measures

3.3.1. Free recall

As the number of details remembered in free recall may be influenced by total verbal output, we first compared the total number of details of Session 2 and Session 3. The mixed 3 (ImRs vs. ImE vs. NIC) × 2 (Session 2 vs. Session 3) ANOVA yielded a significant Condition × Time interaction, $F(2, 116) = 14.04$, $p < .001$, $\eta_p^2 = .20$. However, there was neither a significant main effect of Condition, $F(1, 116) = 1.32$, $p = .27$, $\eta_p^2 = .02$, nor a significant main effect of Time, $F(1, 115) = 2.68$, $p = .10$, $\eta_p^2 = .02$. Post-hoc analysis revealed that the interaction effect was qualified by a significant difference of baseline length of the free recall (Session 2) between conditions, $F(2, 117) = 4.11$, $p = .02$, $\eta_p^2 = .07$. Hence, the total number of details reported in Session 2 was included as a covariate in all following analyses on the free recall data.

Descriptive statistics for correct, incorrect, and total details are presented in Table 3 and illustrated in Fig. 2. The effect of the interventions on voluntary memory measured by free recall was investigated by two mixed 3 (ImRs vs. ImE vs. NIC) × 2 (Session 2 vs. Session 3) ANOVAs for the number of correct and incorrect details, respectively. Looking at the number of correct details, there was a significant main effect of Condition, $F(2, 115) = 5.91$, $p = .004$, $\eta_p^2 = .09$ and a significant main effect of Time, $F(1, 115) = 30.64$ $p < .001$, $\eta_p^2 = .21$. Additionally, there was a significant Condition × Time interaction, $F(2, 115) = 9.74$, $p < .001$, $\eta_p^2 = .15$. Bonferroni-adjusted post-hoc analysis (based on the estimated marginal means) revealed a significant difference in Session 3 between ImRs and ImE ($p < .001$) and a significant difference between NIC and ImE ($p = .01$) showing that after the intervention the number of correctly remembered details increased after ImE, $F(1, 115) = 35.86$, $p < .001$, $\eta_p^2 = .24$, whereas there was no significant change in the number of correctly remembered details in ImRs, $F(1, 115) = 0.09$, $p = .76$, $\eta_p^2 = .00$, and in NIC over time, $F(1, 115) = 0.75$, $p = .39$, $\eta_p^2 = .01$.

Looking at incorrect details, the ANOVA yielded a significant main effect of Time, $F(1, 115) = 19.84$, $p < .001$, $\eta_p^2 = .15$ indicating that the number of incorrectly remembered details decreased over time. However, there was no significant main effect of Condition, $F(2, 115) = 0.47$, $p = .63$, $\eta_p^2 = .01$ or Time × Condition interaction, $F(2, 115) = 1.24$, $p = .30$, $\eta_p^2 = .02$.

3.3.2. Cued recall

Descriptive results for the cued recall are shown in Table 3. The effect of the intervention on voluntary memory measured by a cued recall was examined by three mixed 3 (ImRs vs. ImE vs. NIC) × 2 (Session 3 vs. Session 4) ANOVAs for the sum scores for correct, incorrect and "*I do not know*" answers.

In the two ANOVAs investigating effects on correctly and incorrectly remembered features, no significant effects emerged, main effect of Condition: $F(2, 117) = 0.50$, $p = .61$, $\eta_p^2 = .01$ (correctly remembered), $F(2, 117) = 1.11$, $p = .33$, $\eta_p^2 = .02$ (incorrectly remembered), main effect of Time: $F(1, 117) = 1.69$, $p = .20$, $\eta_p^2 = .01$ (correctly remembered), $F(1, 117) = 0.46$, $p = .50$, $\eta_p^2 = .00$ (incorrectly remembered), Time ×

Table 2
Positive and negative affect (PANAS) pre- and post-intervention for the conditions.

	Condition					
	ImRs (*n* = 40)		ImE (*n* = 40)		NIC (*n* = 40)	
PANAS	*M* (*SD*)	95% CI	*M* (*SD*)	95% CI	*M* (*SD*)	95% CI
Negative affect						
pre-intervention	14.13 (4.19)	[12.79; 15.46]	13.43 (3.78)	[12.22; 14.63]	14.93 (4.91)	[13.35; 16.50]
post-intervention	24.10 (8.73)	[21.31; 26.89]	25.95 (8.24)	[23.32; 28.58]	20.33 (6.74)	[18.17; 22.48]
Positive affect						
pre-intervention	30.73 (7.81)	[28.23; 33.22]	26.68 (5.53)	[24.91; 28.44]	28.45 (6.46)	[26.38; 30.52]
post-intervention	26.35 (7.36)	[24.00; 28.70]	21.90 (5.63)	[20.10; 23.70]	23.48 (5.16)	[21.82; 25.13]

Note. ImRs imagery rescripting, *ImE* imaginal exposure, *NIC* no-intervention control, *PANAS* Positive and Negative Affect Schedule.

Table 3
Results for free recall at sessions 2 and 3, for cued recall and recognition task for sessions 3 and 4.

	Condition					
	ImRs (n = 40)		ImE (n = 39)		NIC (n = 40)	
Free recall	*M* (*SD*)	95% CI	*M* (*SD*)	95% CI	*M* (*SD*)	95% CI
Number of correct details						
Session 2	160.57 (45.02)	[146.18; 174.97]	128.59 (53.84)	[111.14; 146.04]	147.88 (55.83)	[130.02; 165.73]
Session 3	158.55 (41.45)	[145.29; 171.81]	157.38 (49.92)	[141.20; 173.57]	151.35 (51.49)	[134.88; 167.82]
Number of incorrect details						
Session 2	14.38 (9.06)	[11.48; 17.27]	10.41 (6.16)	[8.41; 12.41]	11.23 (7.48)	[8.83; 13.62]
Session 3	11.48 (6.50)	[9.39; 13.56]	10.64 (5.25)	[8.94; 12.34]	10.80 (5.49)	[9.04; 12.56]
Total number of details						
Session 2	206.05 (58.87)	[187.22; 224.88]	163.95 (66.28)	[142.46; 185.43]	186.00 (72.25)	[162.89; 209.11]
Session 3	193.83 (51.14)	[177.47; 210.18]	192.79 (60.10)	[173.31; 212.28]	185.35 (64.98)	[164.57; 206.13]
	ImRs (n = 40)		ImE (n = 40)		NIC (n = 40)	
Cued recall	*M* (*SD*)	95% CI	*M* (*SD*)	95% CI	*M* (*SD*)	95% CI
Correct answers						
Session 3	17.11 (3.47)	[16.00; 18.22]	16.37 (2.80)	[15.47; 17.26]	16.03 (3.28)	[14.98; 17.08]
Session 4	17.02 (4.62)	[15.54; 18.50]	16.62 (2.91)	[15.69; 17.55]	16.78 (3.40)	[15.69; 17.87]
Incorrect answers						
Session 3	11.31 (2.64)	[10.47; 12.16]	11.68 (3.37)	[10.61; 12.76]	10.80 (2.71)	[9.93; 11.67]
Session 4	10.83 (3.37)	[9.76; 11.91]	11.75 (3.38)	[10.67; 12.83]	10.72 (3.70)	[9.54; 11.90]
"*I do not know*"						
Session 3	3.68 (3.08)	[2.69; 4.66]	4.00 (2.58)	[3.17; 4.83]	5.43 (3.04)	[4.45: 6.40]
Session 4	3.58 (3.28)	[2.53; 4.62]	3.70 (2.99)	[2.74; 4.66]	4.73 (3.38)	[3.64; 5.81]
	ImRs (n = 39)		ImE (n = 39)		NIC (n = 40)	
Recognition task	*M* (*SD*)	95% CI	*M* (*SD*)	95% CI	*M* (*SD*)	95% CI
Session 3	7.36 (2.56)	[6.53; 8.19]	7.62 (2.36)	[6.85; 8.38]	7.70 (2.29)	[6.97; 8.43]
Session 4	7.59 (2.79)	[6.69; 8.49]	7.38 (2.61)	[6.54; 8.23]	7.68 (2.62)	[6.84; 8.51]

Note. ImRs imagery rescripting, *ImE* imaginal exposure, *NIC* no-intervention control, *PANAS* Positive and Negative Affect Schedule.

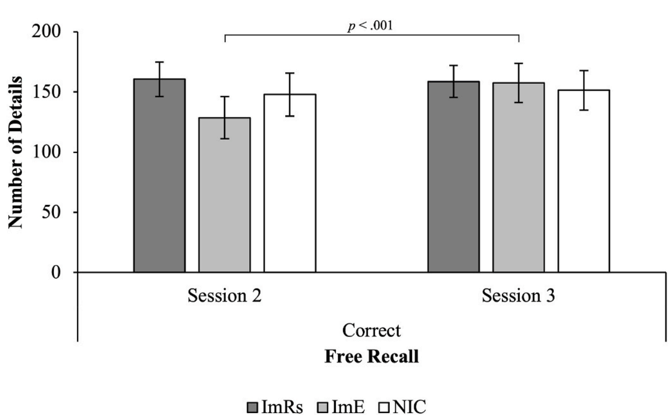

Fig. 2. Results for Free Recall at Sessions 2 and 3.
Note: The number of correctly remembered details in the free recall significantly increased following ImE but not following the other two conditions. *ImRs* imagery rescripting (n = 40), *ImE* imaginal exposure (n = 39), *NIC* no-intervention control (n = 40).

Condition interaction effect: $F(2, 117) = 1.12$, $p = .33$, $\eta_p^2 = .02$ (correctly remembered), $F(2, 117) = 0.47$, $p = .62$, $\eta_p^2 = .01$ (incorrectly remembered).

Looking at the number of "*I do not know*" answers in the cued recall, there was a significant main effect of Time, $F(1, 117) = 5.04$, $p = .03$, $\eta_p^2 = .04$, indicating a decrease in this type of answers from Session 3 to Session 4. However, there was neither a significant main effect of Condition, $F(2, 117) = 2.83$, $p = .06$, $\eta_p^2 = .05$, nor a significant Condition × Time interaction, $F(2, 117) = 1.17$, $p = .32$, $\eta_p^2 = .02$.

3.3.3. *Recognition task*

Descriptive results for the recognition task are shown in Table 3. The effect of the intervention on voluntary memory measured by a recognition task was examined by a mixed 3 (ImRs vs. ImE vs. NIC) × 2 (Session 3 vs. Session 4) ANOVA for the sum scores for correct answers. There was neither a main effect of Condition, $F(2, 115) = 0.10$, $p = .91$, $\eta_p^2 = .00$, nor a main effect of Time, $F(1, 115) = 0.00$, $p = .96$, $\eta_p^2 = .00$, or a Condition × Time interaction, $F(2, 115) = 0.53$, $p = .59$, $\eta_p^2 = .01$, for the number of correct answers in the recognition task.

4. Discussion

This study examined the influence of two imagery-based interventions – namely ImRs and ImE – on voluntary memory of an analogue trauma (measured by a free recall, a cued recall, and a visual recognition task) in a healthy sample. As hypothesized, ImE did increase the number of correctly reported details in the free recall task. However, contrary to our expectations, ImRs did not. Furthermore, neither ImRs nor ImE had an influence on the number of incorrect details reported during free recall. Interestingly, incorrectly remembered details reduced over time in all conditions. Neither in the cued recall nor in the visual recognition task, any differences between conditions emerged. In summary, we found no negative effects of ImRs and ImE on memory accuracy. In contrast, there is evidence that ImE may actually improve the validity of autobiographical memory as we found an increase in correct details in free recall following ImE.

Overall, the findings suggest that involuntary and voluntary memory systems can be selectively and independently targeted. This is in line with suggestions from basic memory research (e.g., Visser et al., 2018) as well as separate-trace accounts of PTSD (Brewin et al., 1996, 2010;

Dalgleish, 2004), and mirrored by results of earlier studies (e.g., James et al., 2015; Krans et al., 2010), in which involuntary re-experiencing was reduced while voluntary recognition memory remained intact. This means that not all imaginative interventions necessarily have the same effects on voluntary memory.

The emerging literature on the effects of trauma-focused interventions on voluntary trauma memory, including the current study, has important implications for clinical and legal practice. Specifically, findings suggest that it is possible to reduce intrusive memories via psychological interventions without impairing voluntary memory and thus the quality of testimony in the context of legal trials.

How do our – and similar earlier findings – then align with earlier research showing the potential of imagery-based interventions to distort voluntary memory? In order to answer this important question, it appears necessary to focus more on the specific procedural details used in psychological treatment (e.g., ImRs or ImE) vs. procedures used in research on memory distortion.

Theoretically, it could be assumed that the repeated rehearsal and retrieval taking place in ImE and ImRs strengthens the association between C-reps and S-reps (Brewin et al., 1996, 2010; Dalgleish, 2004), which should in turn enhance the elaboration and organization of memory facilitating the verbal accessibility of voluntary memory (as reflected in the increased number of correct details in free recall) (Brewin, 2014). However, in our study this beneficial effect emerged only for ImE, not for ImRs. One possible explanation for this differential effects of ImE and ImRs on voluntary memory in this study may be an imbalance of the two interventions with respect to rehearsal and testing effects due to the repetition and re-encoding of the memory (Rowland, 2014). While participants in the ImRs condition repeated the film scene only until the hotspot and rescripted what happened afterwards, participants in the ImE condition repeated all the details they saw throughout the whole film scene not only in the intervention session but also afterwards (by listening to the audio recording). This assumption is also in line with the results of Romano et al. (2020) who observed an increase of remembered details specifically for those aspects that have been focused in the different interventions. While they found an increase only in positive and neutral details after ImRs, all kinds of details (positive, neutral, and negative) increased after ImE. This suggests that the effect of imagery interventions on memory accuracy (i.e., number of remembered details) might depend on what exactly is repeated within an intervention (i.e., type and number of details). The fact that Romano et al. (2020) found an increase in remembered details following ImRs and we did not could be due to a methodological difference: instead of classifying the remembered details as positive, neutral, and negative, we assessed correct and incorrect details.

However, one earlier study by our group did find positive effects of ImRs on voluntary memory (e.g., Ganslmeier et al., 2022). This could be due to the fact that the hotspot in the present study (based from the trauma film) was rather early. In contrast, Ganslmeier et al. (2022) used a modified version of the Trier Social Stress Test (TSST; Kirschbaum et al., 1993) as an aversive autobiographical event in their study, and participants could decide individually which of the three tasks they had performed within the TSST (interview, arithmetic task, singing) represented the hotspot. Since some participants chose the second or even the third task as the hotspot, rehearsal and elaboration took place for a much larger proportion of the event memory in the earlier study than in the current one.

For the cued memory recall and the newly implemented visual recognition task, we did not find any changes from pre to post intervention – independently of the intervention condition. This is in line with other studies that used a cued recall (Ganslmeier et al., 2022; Siegesleitner et al., 2019). However, Hagenaars and Arntz (2012) found an improvement in cued recall after ImRs and ImE (compared to positive imagery of a personal, pleasant event), which may have been due to the facts that trauma film and intervention took place on the same day and that the control condition was different from ours. Both may have complicated (re)consolidation in their positive imagery condition: in contrast to the NIC in this study, in which participants repeated (within the free recall) what they had seen after sufficient consolidation time, participants in the positive imagery condition of Hagenaars and Arntz (2012) did not repeat the analogue trauma but imagined alternative material on the same day they saw the trauma film, which may have competed with the memory trace of the trauma film. This may have resulted in a greater disadvantage in their positive imagery condition and thus a greater difference between their control condition and ImRs or ImE than we observed when comparing ImRs and ImE to our NIC.

The fact that neither ImRs nor ImE had a negative impact on subjects' recall, i.e., no reduction in correct details, is particularly interesting in light of the Source Monitoring Framework (Johnson, 2006; Johnson et al., 1993). Here, it is assumed that imagined events may be mistaken for actual events based on similarity. Whereas in ImE participants are only exposed to the original experience in their imagination, ImRs additionally aimed to integrate helpful perspectives by explicitly modifying the mental image of the traumatic memory. Hence, at first sight source monitoring errors may seem to be more likely in ImRs. However, the current findings do not suggest that voluntary memory is altered by scenarios that are imagined within ImRs. One reason could be that in our study the alternative script was predominantly generated by the participants themselves. There is some evidence from the earlier false memory research (e.g., Foley et al., 2006) that the source of the imagery script (generated by oneself vs. by another person) can have an impact on error rates or false memories: When participants (rather than someone else) created the scripts of their imagery themselves, the rate of false memories was significantly lower. Similarly, the source monitoring model predicts that source errors are more likely when images are generated unintentionally than when they are generated intentionally as intentional cognitive operations help to ensure that the modification of the memory was generated internally and thus facilitate discrimination between imagined and experienced events (Henkel & Carbuto, 2008). However, asking participants to generate the script themselves may not be the only factor preventing ImRs to lead to impairment of voluntary event memory. In addition, ImRs explicitly marks the integration of new information into memory (i.e., explicitly instructs the patient to imagine an alternative, less stressful outcome from the worst moment [hotspot] onwards) making participants aware of the cognitive operations of the ImRs procedure and thus potentially preventing memory bias.

The finding that ImRs did not distort declarative memory of the film scene is also in line with the supposed working mechanisms of ImRs (Arntz, 2012; Arntz & Weertman, 1999). It is assumed that ImRs does not erase or replace the existing memory trace but that it rather changes the meaning of the trauma by the formation of a new and less stressful memory representation. According to the retrieval competition hypothesis (Brewin, 2006), this new and more positive memory representation increasingly wins the retrieval competition with the original negative memory when treated successfully with ImRs (Brewin et al., 2009).

To sum up, there was neither evidence in previous studies (Ganslmeier et al., 2022; Hagenaars & Arntz, 2012; Siegesleitner et al., 2019) nor in this study that trauma-focused treatment for PTSD in the form of imagery-based interventions distorts recall in the cued or free recall or recognition task. If anything, our results suggest that memory may even improve following imagery-based interventions. Hence, deterioration as hypothesized in basic false memory research (Garry et al., 1996; Goff & Roediger, 1998; Nash et al., 2009; Thomas & Loftus, 2002) and legal practice (Volbert & Steller, 2014), was not observed. We share the skepticism of other researchers (Patihis et al., 2018) about predicting memory distortions in real world situations in general – and in the context of psychological interventions specifically – based on experimental basic research alone. Patihis et al. (2018) showed that false memory production in one laboratory task does not reliably predict false memory production in other tasks. Against this background, instructions that are given in an experiment or intervention as well as the indices that are used to measure memory change may play a decisive role. While the aforementioned basic memory studies used imagination inflation and memory implantation techniques that actively queried or suggested additional, non-experienced information, the instructions in ImRs and ImE differ fundamentally in this regard. For ImRs, the modification of the script is made transparent and is usually more likely to be implemented by the participants themselves, whereas in basic research studies the suggestion comes from externally. As in ImE, participants are not instructed to change anything in the script, it seems unlikely that this leads to deterioration or increase of incorrect details in declarative memory. In addition, the basic research studies used confidence ratings as a dependent variable, whereas we used memory accuracy as an index for memory change. Since both are not necessarily related (Roediger et al., 2012; Scoboria et al., 2014), it appears questionable to draw conclusions about memory changes based on findings referring to memory confidence ratings.

Before drawing final conclusions some limitations of the current study have to be kept in mind. First, the use of an analogue trauma is crucial to reliably investigate the effects of imagery-based interventions on the accuracy of voluntary memory, as only then it is possible to know whether the loss or addition of memory details equals an increase or decrease in memory accuracy. The trauma film paradigm used in our study is a standard analogue task used to test responses to stress and trauma without actually exposing participants to real traumatic events, which would be ethically unacceptable (Arnaudova & Hagenaars, 2017). However, reactions to simulated trauma are not as intense as reactions to real-life personal trauma and our analogue trauma is of course not equivalent to real trauma, which limits the generalizability of our results to clinical samples (Brewin, 2007). Nevertheless, it has been shown that the paradigm (and especially the film Irréversible) is a useful method to induce analogue post-traumatic stress symptoms such as intrusive memories, negative emotions, and subjective distress (Arnaudova & Hagenaars, 2017) supporting the construct validity of the analogue design (see Vervliet & Raes, 2013). The results of this study also showed that the trauma film caused a large increase in negative affect and a large decrease in positive affect. Additionally, it triggered as many intrusions as various trauma films did in previous studies (Arnaudova & Hagenaars, 2017). In addition, by using an anxious sample, we used a sample that responds with more analogue flashbacks to trauma film than a less anxious sample (Clark et al., 2015). Second, as in previous analogue studies (Ganslmeier et al., 2022; Hagenaars & Arntz, 2012; Siegesleitner et al., 2019), we conducted only one single intervention session, which is at the very low end of the spectrum compared to clinical trials (average number of sessions: 4.5, with a range of 1–16; Morina et al., 2017). Nevertheless, single session interventions have also been shown to be effective (Grunert et al., 2007). In this analogue study, however, the interventions did not show the expected positive effects on mood and intrusive re-experiencing demonstrated in the therapeutic context. Therefore, the question arises whether our results can be generalized to therapeutic situations. Future studies should address this question by increasing the dose of the intervention to test whether negative effects on voluntary memory are omitted even when the interventions show the desired positive effects on analogue symptoms. Another limitation of this study is that the interval between trauma film and intervention was rather short. Whereas in clinical practice, there are often months or years between trauma and clinical treatment, it was only one day in the current study. In accordance with the Source Monitoring Framework (Johnson, 2006; Johnson et al., 1993), one can assume that older memories partially degrade over time and may be more susceptible to unintentional intervention effects in clinical practice. However, there is also evidence that traumatic memories (compared to non-traumatic ones) are retrieved more reliably and can usually be remembered well over time (Brewin, 2011; Goodman et al., 2017; Peace & Porter, 2004). This suggests that personal relevance is more crucial than time and implies that highly emotional memories, despite their age, are more likely to be difficult to change than younger, significantly less emotional memories. Nonetheless, the timing and dose of the interventions differs from the use of ImRs in clinical setting, which again is inherent to the analogue paradigm used. Due to short time period between event and intervention as well as the low intervention dose, our paradigm would clearly not be suitable to test effects of the intervention on symptomatology. This may also be reflected by the lack of intervention effects on mood and intrusions found in the current study. However, the aim of our study was to test the effects of ImRs on voluntary memory. Here, we do not see any reason to assume that a potential impact of ImRs on memory accuracy is strongly dependent on timing and dose. This view is shared in the extant literature (e.g., Garry et al., 1996; Goff & Roediger, 1998; Nash et al., 2009; Thomas & Loftus, 2002); for examples, studies testing the implantation of false memories have also used rather brief interventions shortly after the event memory has formed. Nevertheless, it would be interesting if future studies examined this with longer time intervals. In sum, we argue that both the trauma film paradigm for inducing event memories and the ImRs intervention in our study demonstrate reasonable construct validity and are widely accepted in the literature. Our research necessitated the use of an analogue paradigm since testing it in real clinical settings was not feasible. Nevertheless, it is important to acknowledge that factors like event severity, time between the event and intervention, and dose (single vs. repeated intervention) could potentially influence the outcomes. For example, ImRs may only lead to reduced memory accuracy if the modified script is imagined repeatedly. However, we believe that these factors do not undermine the current study's findings but rather pose important questions that should be addressed in future research.

In summary, given the lack of specific research in this area, this study adds important new findings to the ongoing debate about the extent to which imagery-based interventions might reduce recall accuracy of traumatic life events. Our findings as well as other studies in this area call into question the view that testimony about traumatic experiences is less valid in court after imagery-based systematically investigate and specify the circumstances under which voluntary memory might be impaired by TF-CBT, in order to help both trauma survivors and their therapists out of the dilemma between therapeutic and legal concerns.

Ethical approval

The study was approved by the local ethics committee and was conducted in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Role of funding source

Maximilian Ganslmeier received a doctoral grant from the Hanns-Seidel-Stiftung. The funding source had no involvement in the study design, in the collection, analysis or interpretation of data, in the writing of the report or in the decision to submit the article for publication.

CRediT authorship contribution statement

Maximilian Ganslmeier: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Project administration, Funding acquisition. **Thomas Ehring:** Methodology, Resources, Writing – review & editing. **Larissa Wolkenstein:** Conceptualization, Methodology, Resources, Writing – review & editing, Supervision, Funding acquisition.

Declaration of generative AI and AI-assisted technologies in the writing process

AI and AI-assisted technologies in the writing process were not used.

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.

Data availability

Anonymized data have been made publicly available at the https://osf.io/ and can be accessed at https://osf.io/5ysbh/?view_only=7a34332db7ad4f9480a2cda3eec0f2be.

Acknowledgements

The development of the Tellmi experience sampling app was funded by a grant from the German Research Foundation to Felix Schönbrodt (SCHO 1334/5-1).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.brat.2023.104409.

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