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Effects of Imagery Rescripting on Emotional Responses During Imagination of a Socially Aversive Experience

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Abstract
Imagery rescripting (ImRs) of socially aversive memories is a promising intervention in the treatment of Social Anxiety Disorder. Little is known about the effects of ImRs on physiological responses to the rescripted socially aversive memory, which was the focus of this study in a healthy sample. Thirty individuals performed an imagination task measuring psychophysiological responses and subjective feelings (post-hoc) related to the rescripted memory, as well as to two control memories. In a within-subject design, participants completed the imagination task before and after a control intervention, and subsequently after one session ImRs of the socially aversive memory. At one-week follow-up, lasting effects on social anxiety and subjective feelings were assessed online ($N = 26$). ImRs of the socially aversive memory resulted in a significant reduction in negative feelings and activity of the corrugator supercilii, as well as a significant increase in valence and positive feelings related to the socially aversive memory compared to both control memories. However, only effects for positive feelings and corrugator supercilii were significantly stronger for ImRs compared to the control intervention. Lasting effects appeared for fear of negative evaluation and subjective emotional responses to the rescripted memory. These findings give preliminary evidence for the impact of ImRs on emotional aspects of the rescripted memory, indicating that ImRs might work through changing the representation of the aversive event in memory.

Keywords social anxiety; unconditioned stimulus revaluation; psychophysiology; posttraumatic memory characteristics

Imagery rescripting (ImRs) is a transdiagnostic psychotherapeutic intervention taking into account the importance of aversive events as a core etiological feature in many psychiatric disorders (e.g., Grunert et al., 2013; Nilsson et al., 2012; Norton & Abbott, 2016; Smucker & Neiderdee, 1995). Attaining promising effects in the treatment of Posttraumatic Stress Disorder (PTSD, e.g., Grunert et al., 2003; Smucker & Neiderdee, 1995), ImRs was also found to reduce symptoms in Social Anxiety Disorder (SAD, e.g., Lee & Kwon, 2013; Nilsson et al., 2012; Norton & Abbott, 2016; Reimer & Moscovitch, 2015; Wild et al., 2007; 2008). However, underlying mechanisms of ImRs still remain largely unknown. Unconditioned stimulus (UCS) revaluation theory suggests that ImRs leads to changes in the (emotional) meaning of the memory (representation of the UCS), impacting the association of the conditioned stimulus (CS) with the UCS and thus modulating the intensity of the conditioned response (Arntz, 2011, 2012; Davey, 1989). Accordingly, previous studies in SAD, PTSD as well as in healthy samples found that ImRs impacts emotional responses to the rescripted memory, such as distress, valence, fear, sadness or guilt (e.g., Arntz et al., 2007; Kunze et al., 2019; Siegesleitner et al., 2019; Strohm et al., 2019; Lee & Kwon, 2013; Nilsson et al., 2012; Romano et al., 2020; Wild et al., 2007). Related to these findings, ImRs was also found to have an effect

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on other aspects of the memory, such as vividness and cognitions (Hagenaars & Arntz, 2012).

Despite of the growing evidence regarding ImRs effects on self-reported emotional responses, until now, only few studies have investigated the impact of ImRs on psychophysiological correlates. Previous studies revealed reductions in heart rate (HR) during ImRs in participants with increased health anxiety (Tolgou et al., 2018), as well as increased heart rate variability in response to social stress after ImRs in SAD patients (Hyett et al., 2018). While these studies provide preliminary evidence that ImRs in general affects psychophysiological parameters during and also after the intervention, until now little is known about psychophysiological responses to the rescripted memory. Strohm and colleagues (2021) were the first to investigate effects of ImRs compared to a control intervention (positive imagery) on psychophysiological responses during reactivation of the rescripted memory in a nonclinical sample. They found a reduction in HR (as an indicator for arousal) and activity of the corrugator supercilii (as an indicator for valence) for both interventions, however no differences between the interventions. There are no studies up to date investigating ImRs effects on psychophysiological responses to a socially aversive memory. Previous studies on psychophysiological responses to socially aversive memories in general (without ImRs) report attenuated physiological arousal (skin conductance level, HR) in SAD patients, as well as negative valence (activity of the corrugator supercilii) in SAD patients and healthy controls during reactivation of the memories (e.g., Cuthbert et al., 2003; McTeague et al., 2009; Sansen et al., 2015). Psychophysiological correlates of positive valence (activity of the zygomaticus major, e.g., Cacioppo et al., 1986) have not yet been investigated, even though previous studies also found ImRs effects on self-reported positive emotionality (Çili et al., 2016; Kunze et al., 2019).

The aim of this study was to further investigate the effects of ImRs on the emotional response to a socially aversive memory with a special focus on psychophysiological measures in a healthy sample. We investigated the effect of ImRs on a socially aversive memory, as ImRs plays an important role in the treatment of SAD and the experience of such events at some point in life is also common among healthy individuals (e.g. Bjornsson et al., 2020; Erwin et al., 2006; Moscovitch et al., 2018). To investigate ImRs effects specific to the rescripted socially aversive memory, two control memories (generally aversive, neutral), which were not rescripted were used for comparison. In addition to that, prior to ImRs an active control intervention (answering questions regarding certain details of the event) was conducted. Lasting effects of the single ImRs session on fear of negative evaluation, social anxiety and subjective feelings were examined online at one-week follow-up. We expected ImRs to alter self-reported feelings (decrease: negative feelings, arousal; increase: positive feelings, valence) and psychophysiological responses (decrease: HR, skin conductance responses (SCRs), corrugator supercilii; increase: zygomaticus major) regarding the socially aversive memory compared to two control memories and an active control intervention. Moreover, we expected a decrease in fear of negative evaluation and social anxiety, as well as changes in subjective feelings regarding the socially aversive memory one week after ImRs. In addition to that, we investigated emotional responses to the three memory conditions during the imagination task at baseline, as well as ImRs effects on posttraumatic memory characteristics and memory-related cognitions.

Method

Participants

Thirty-three students recruited from the local university participated in this study. Exclusion criteria were current or past self-reported mental or physical illnesses, current medication affecting the central nervous system, and recent (within the last three months) or regular drug abuse. Participants received course credits as compensation for their participation. Three participants were excluded because of early termination of the experimental session (n = 1), or technical problems during data acquisition (n = 2), leaving a final sample of 30 participants (for demographics, see Table 1), 26 of whom also completed the follow-up online assessments one week after the experimental session. Sample sizes in previous studies investigating effects of ImRs in SAD patients were also in this range or smaller (e.g., Lee & Kwon, 2013; Reimer & Moscovitch, 2015; Wild et al., 2007, 2008). Regarding power analysis, effect sizes for ImRs on social anxiety, as well as self-report measures concerning imagery/memory distress and vividness were reported to be large in previous studies on patients with SAD (Lee & Kwon, 2013; Nilsson et al., 2012; Wild et al., 2008; Norton & Abbott, 2016). There are no studies up to date investigating the effects of ImRs of a socially aversive memory in healthy participants, and especially on psychophysiological responses. Tolgou et al. (2018) reported medium effect sizes for effects of ImRs on HR in a sample of students with high levels of health anxiety. Prior to study conductance we determined the sample size for medium effect sizes (28 participants, d = 0.5) to detect significant within-factor interaction effects at power of .8 (G*Power, Version 3.1.9.2, Faul et al., 2007). Written informed consent was obtained from all participants and the study

protocol was approved by the local Ethics Committee. The trial was registered retrospectively at the German Clinical Trial Register (DRKS00021173).

Table 1. Sociodemographic Variables and Questionnaires

variable		
sex, female (%)	86.7	
age, *M*(*SD*), *range*	22.80 (3.48)	19 – 32
social anxiety, *M*(*SD*), *range*		
FNES	48.27 (10.16)	30 – 72
SPIN	15.42 (12.88)	0 – 49
depression, *M*(*SD*), *range*		
BDI-II	7.73 (5.27)	0 – 23
anxiety, *M*(*SD*), *range*		
state (STAI-S)	36.20 (7.16)	22 – 53
trait (STAI-T)	38.03 (7.35)	27 – 54
emotion regulation, *M*(*SD*), *range*		
expressive suppression (ERQ)	3.06 (1.16)	1.25 – 5.50
cognitive reappraisal (ERQ)	4.56 (0.94)	2.67 – 6.00

Note. Means (*M*) and standard deviations (*SD*) and range or percentage (%) of sociodemographic variables and questionnaires. FNES: Fear of Negative Evaluation Scale; SPIN: Social Phobia Inventory; BDI-II: Beck's Depression Inventory II; STAI-S/-T: Stait-Trait-Anxiety Inventory – State/Trait; ERQ: Emotion Regulation Questionnaire.

Experimental Procedure

Each participant was invited for a single session (for overview see Figure 1). First, the autobiographical interview was conducted. Participants further filled in questionnaires concerning social anxiety, depressive symptoms, emotion regulation strategies, posttraumatic stress symptoms, state and trait anxiety, as well as memory appraisals. Afterwards, a psychophysiological baseline measurement, where participants were instructed to relax and close their eyes or fixate on a point in the room, as well as a face processing task were performed (data will be reported elsewhere). After that, the imagination task as well as memory appraisal ratings were conducted. Subsequently, the control intervention was performed, followed by the imagination task, as well as the memory appraisal ratings. Finally, the experimental intervention (ImRs of the socially aversive memory) was conducted. Afterwards the imagination task was performed again and participants filled in the memory appraisal ratings. One week later, participants were asked to complete questionnaires concerning fear of negative evaluation, social anxiety, as well as the memory appraisal ratings via the online tool Socsisurvey (Leiner, https://www.socsisurvey.de).

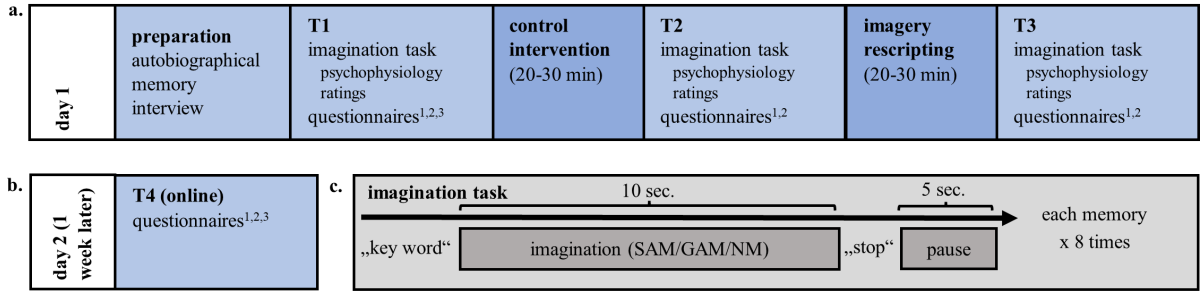
Autobiographical Memory Interview

The purpose of this interview was to collect data about three different autobiographical situations: 1) neutral memory, e.g., grocery shopping, 2) generally aversive memory, e.g., death of grandparent, 3) socially aversive memory, e.g., poor performance in public. Participants were asked to describe each situation and answer questions concerning the emotional state and cognitions during each situation, as well as the presence of other people, and their and the participants' behavior. In addition, participants selected an individual keyword for each of the three situations (for a detailed description see Supplement A).

Imagination Task (Subjective and Psychophysiological Emotional Response)

The procedure of the imagination task was adapted from previous studies on imagery in SAD (McTeague et al., 2009; Sansen et al.; 2015). Instead of sentences/scripts, participants were presented with one keyword for each situation in order to facilitate modifications to the imagination of the original memory in the course of the study. The keywords selected in the autobiographical memory interview were spoken and recorded by the experimenter and presented to the participants via headphones in a randomized order for eight times each. After the presentation of each keyword, participants were instructed to imagine the situation indicated by the keyword for a duration of 10 sec., as vividly as possible. A 5 sec. break was implemented after each 10 sec. of imagination, indicated by an auditory cue ("stop"). This procedure was repeated for 24 times (for overview see Figure 1c). The total duration ranged from approximately six to seven minutes, depending on the duration of the individual keywords' audio segment. Prior to the task, participants were instructed to close their eyes or fixate on a point in the room and adjust the volume of the headphones. A training trial (each keyword was presented once) was conducted before the experiment to ensure that participants knew how to perform the task. During the task psychophysiological data were recorded. Directly after the task participants rated their positive and negative feelings with regard to each memory condition during the task using 9-point unipolar rating scales ranging from 0 ("not at all") to 8 ("extremely") and valence and

Figure 1. Schematic Description of Experimental Protocol (a, b) and Imagination Task (c)



Note. Experimental protocol: **a.** At day 1 (laboratory session), an autobiographical memory interview, control intervention and Imagery Rescripting of the socially aversive memory as well as assessment of the imagination task (psychophysiology, ratings) and questionnaires ([1]memory appraisal, [2]cognitions and posttraumatic memory characteristics, [3]social anxiety (in general)) were conducted. **b.** One week after day 1 at day 2 (online measurement) questionnaires ([1]memory appraisal, [2]cognitions and posttraumatic memory characteristics, [3]social anxiety (in general)) were assessed via an online tool. **c.** Imagination task: one trial of the imagination task, beginning with the auditory presentation of an individual keyword, imagination of the corresponding memory condition (10 sec.), ending with an auditory stop signal, and a break (5 sec.) before the next keyword was presented. After the imagination task, participants rated their emotional responses during the task to the three memory conditions. During the imagination phase, psychophysiological data were measured. The imagination task consisted of 8 trials for each condition (socially aversive memory [SAM], generally aversive memory [GAM], neutral memory[NM]) in a pseudorandomized order (24 trials altogether).

arousal using the Self-Assessment Manikins on a bipolar scale from 0 ("unpleasant"/ "calm") to 8 ("pleasant"/ "excited"; Bradley & Lang, 1994).

Self-Report Data

Social Anxiety and Fear of Negative Evaluation.

Social Anxiety. Intensity of social anxiety was assessed with the German version of the self-report questionnaire Social Phobia Inventory (SPIN; Connor et al., 2000; Sosic et al., 2008). The SPIN consists of 17 items rated on a 5-point-scale from „not at all" to „extremely" and has demonstrated good reliability (Cronbach's α = .87 - .94 [patients with SAD] and Cronbach's α = .82 - .90 [healthy controls]; Connor et al., 2000; Sosic et al., 2008).

Fear of Negative Evaluation. The Fear of Negative Evaluation Scale (FNES; Vormbrock & Neuser, 1983; Watson & Friend, 1969) is depicting on one part of social anxiety namely the fear to make a negative impression on other people, using 20 items. Vormbrock and Neuser (1983) report a good internal consistency (Cronbach's α = .92) for the German version.

Memory Appraisal Ratings. Since the follow-up timepoint was an online assessment, no data was gathered regarding the imagination task. To obtain information about changes in emotional responses, memory appraisal ratings resembling the ratings of the imagination task were collected during the experimental session (T2) and at the follow-up timepoint (T4). Memory appraisal ratings and ratings of the imagination task were (highly) correlated at T2 (r = .394 – .923). Valence and arousal ratings with regard to the autobiographical memories were assessed using the Self-Assessment Manikins on a bipolar scale from 0 ("unpleasant"/ "calm") to 8 ("pleasant"/ "excited"; Bradley & Lang, 1994). Negative and positive feelings were rated on 9-point scales ranging from 0 ("not at all") to 8 ("extremely"). Participants were instructed to think about the memories and indicate their current emotional state while remembering ("Please indicate how your emotional state is now when you remember the […] situation.").

Further Measures. Several more questionnaires regarding depressive symptoms, emotion regulation strategies, state and trait anxiety, as well as memory-related cognitions and post-traumatic memory characteristics were conducted (for a more detailed description see Supplement B).

Psychophysiological Data Assessment, Reduction, and Analysis

Psychophysiological data were recorded (1,000 Hz) with the actiCHamp Plus amplifier and the Brain Vision Recorder software.

Electromyography. The muscle activity of the left corrugator supercilii and zygomaticus major were assessed using 4 mm Ag/AgCl electrodes placed according to the recommendations of Fridlund and Cacioppo (1986). The recording was subdivided into segments for each trial ranging from -1,000 msec. to 10,000 msec. relative to the presentation of the keyword. Data were preprocessed and analyzed using Brain Vision Analyzer 2 (Brain Products, Gilching, Germany). Raw data were screened and artifacts were corrected manually. To analyze the data, they were

Table 2. Baseline differences (T1) in emotional responses between the three memory conditions

	SAM vs GAM vs NM			
	F	*df*	*p*	*partial η²*
subjective feelings				
negative feelings	44.43	2, 58	<.001*	.605
positive feelings	8.32	2, 58	.001*	.223
valence	33.15	2, 58	<.001*	.533
arousal	16.71	2, 58	<.001*	.366
psychophysiology				
corrugator supercilii	10.26	2, 50	<.001*	.291
zygomaticus major	0.31	2, 44	.736	.014
ECG (IBI)	1.38	2, 54	.260	.049
SCRs	0.02	2, 42	.984	.001

Note. SAM = socially aversive memory, GAM = generally aversive memory, NM = neutral memory. *F*-statistics, significance level (*p*), effect sizes (*Cohen's d*). ECG = electrocardiogram; IBI = interbeat-interval; SCRs = skin conductance responses. Bonferroni-Holm correction for subjective feelings.

filtered (high-pass: 30 Hz), rectified, smoothed (high cutoff 8 Hz, fourth order Butterworth filter) and baseline corrected (-1,000 to 0 msec.). An average activation was calculated for each trial and each muscle.

Skin Conductance Responses. SCRs were measured using Ag/AgCl electrodes (5 mm) placed on the non-dominant hand and filled with isotonic electrolyte medium. Data were preprocessed and analyzed using MATLAB R2018B (The MathWorks, Natick, MA, USA) with the toolbox Ledalab 3.4.4 (available under www.ledalab.de). Raw data were downsampled to 100 Hz and smoothed (32 sample full width at half maximum Gaussian kernel). Participants with less than one response (responses <0.01µS were considered to be zero) were categorized as nonresponders and were excluded (n = 1). All data were screened manually for artifacts. Through-to-peak (TTP) analysis in Ledalab 3.4.4 (Benedek & Kaernbach, 2010) was used to extract the response with the maximum amplitude starting during the imagination phase (analysis time window: 0.8 – 10 sec. after start of the imagination phase).

Heart Rate. For electrocardiogram (ECG) measurement, three disposable foam electrodes (TIGA-MED Gold, TIGA-MED Deutschland GmbH, Ronneburg, Germany; diameters: adhesive foam = 43 mm, pre-filled solid gel = 16 mm, Ag/AgCl electrode = 7.5 mm) were applied on the left chest (one over the sternum, one over the heart) and the left flank. The ECG was filtered (low cut-off 1Hz and high cut-off 30 Hz, fourth-order two-way Butterworth filter), and the EKG Markers solution in Brain Vision Analyzer 2 (Brain Products, Gilching, Germany) was used to detect R spikes automatically. Artifacts were corrected manually. The ECG was converted to interbeat intervals (IBI) using MATLAB scripts (Mueller et al., 2013; MATLAB Version R2019a; The MathWorks, Natick, MA). The IBI time series were then subdivided into segments for each trial ranging from -1,000 to 10,000 msec. relative to the presentation of the keyword for each memory condition. After that, the IBI time series were baseline-corrected relative to -1,000 to 0 msec. and an average was determined for each memory condition.

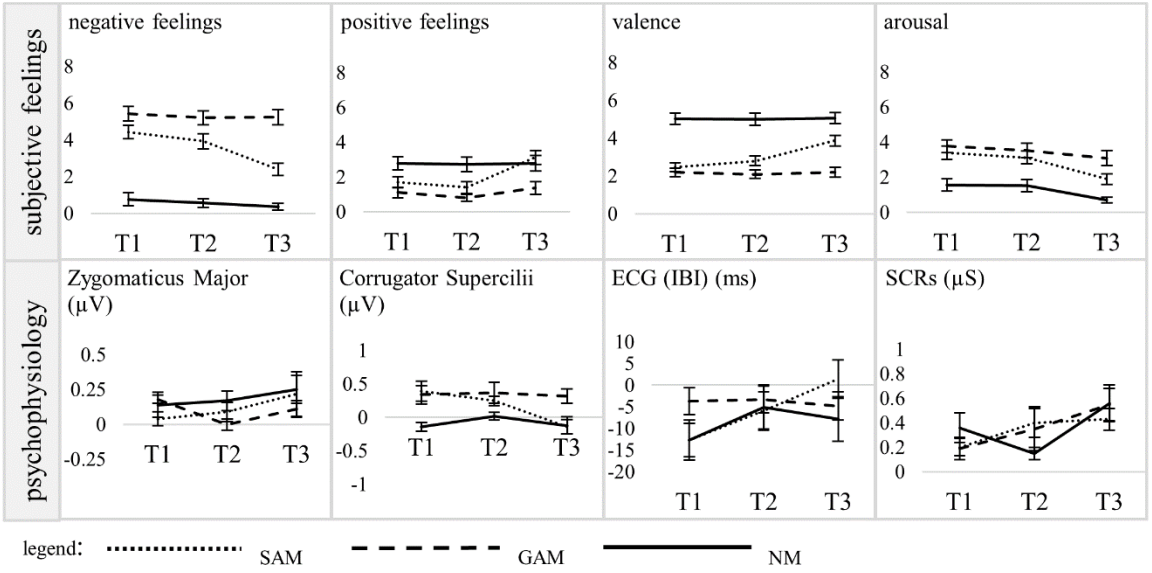
Experimental Intervention

The experimental interventions (control intervention, ImRs) were only conducted for the socially aversive memory, not for the neutral memory or the generally aversive memory.

Control Intervention (Duration 20 – 30 Min). During the control intervention participants were instructed to write down and discuss what they remembered in detail about the socially aversive situation. In order to adjust the procedure to the ImRs procedure it was divided into three different questions: about the situation in general, the location of the event and other people involved. After each question, the experimenter left the room for three minutes and the participants were asked to write down what they remembered. Subsequently, the participants were instructed to tell the experimenter what they wrote down. After summarizing, the experimenter asked more questions concerning details of the situation (e.g., sensory impressions). Psychophysiological data were recorded during the control intervention (data will not be reported in this manuscript).

Imagery Rescripting of the Socially Aversive Memory (Duration 20 – 30 Min). ImRs was performed by the experimenter following a protocol adapted from Wild and Clark (2011) which has already been used in several studies (Nilsson et al., 2012; Norton & Abbott, 2016; Wild et al., 2007, Wild et al., 2008; for detailed description see Supplement C). The protocol was divided into three phases: During the first phase participants were asked to go back in their socially aversive situation and imagine re-experiencing

Figure 2. Changes in responses to the three memory conditions during the experimental session



Note. SAM = socially aversive memory; GAM = generally aversive memory; NM = neutral memory. ECG = electrocardiogram; IBI = interbeat interval; SCRs = skin conductance responses. T1 = baseline; T2 = after the control intervention; T3 = after Imagery Rescripting.

the situation as their former self. In the second phase, participants described the same scene, now from an observer perspective, as their current adult self and carried out changes to the original memory. In the third phase, the participants relived the situation again from the perspective of their younger self but with all the changes introduced by the adult self. Psychophysiological data were recorded throughout the procedure (data will not be reported in this manuscript).

Statistical Analyses

The Statistical Package for the Social Sciences software 24.0 (SPSS software 24.0; IBM Corporation, Armonk, NY, USA) for Windows was used to conduct all statistical analyses. The level of significance was determined at α = .05 (Bonferroni-correction for subjective feelings). Prior to analysis, participants differing more than two standard deviations from the mean in psychophysiological measures were excluded list-wise. Repeated-measure ANOVAs were used to analyze baseline differences at T1 with memory condition (socially aversive vs generally aversive vs neutral) as within-subject factor. Post-hoc pairwise comparisons between the memory conditions at T1 were analyzed using paired *t*-tests. To examine effects of the active control intervention and ImRs on subjective and physiological responses to the socially aversive memory we used repeated-measure ANOVAs with memory condition (socially aversive vs generally aversive vs neutral) and timepoints (T1 vs T2 vs T3) as within-subject factors. Effects of ImRs at one-week follow-up were also analyzed using repeated-measure ANOVAs (only subjective data available). Memory condition × timepoints interaction effects are the critical effects for the hypotheses tested (main effects will not be reported in this manuscript). For significant interaction effects further post-hoc analyses were conducted using repeated-measure ANOVAs and paired *t*-tests. To specifically analyze ImRs effects compared to the active control intervention, paired *t*-tests were calculated (T2 - T1 vs T3 - T2 [T2 - T1 vs T4 vs T2 for follow-up]). Paired *t*-tests were used to analyze changes in fear of negative evaluation and social anxiety (T1 vs T4). In addition, an exploratory correlational analysis between symptom severity (social anxiety, fear of negative evaluation) and ImRs effects on memory-related variables for the socially aversive memory (T2 vs T3) was conducted.

Results

Baseline Differences in Emotional Responses Between the Three Memory Cognitions

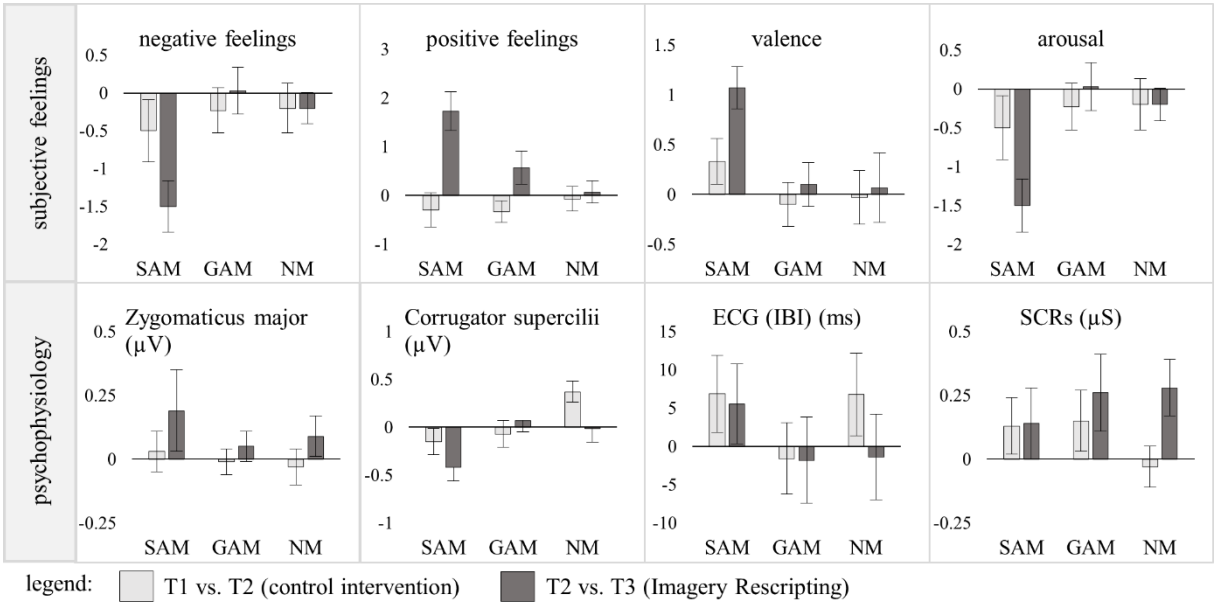
Subjective Feelings. Significant differences between the three memory conditions at T1 were found for negative feelings, positive feelings, valence and arousal (see Table 2, for descriptive statistics see Supplementary Table 1). Post-hoc analyses revealed that negative feelings and arousal were rated

Table 3. Post hoc tests of effects of the active control intervention and Imagery Rescripting on emotional responses to the socially aversive memory compared to both control memory conditions

	memory comparison	intervention effects (T1 vs T2 vs T3)				control intervention (T1 vs T2)				imagery rescripting (T2 vs T3)			
		F	*df*	*p*	*partial η²*	*F*	*df*	*p*	*partial η²*	*F*	*df*	*p*	*partial η²*
subjective feelings													
negative feelings	SAM vs GAM	12.45	2, 58	<.001*	.300	0.42	1, 29	.523	.014	19.53	1, 29	<.001*	.402
	SAM vs NM	4.69	2, 58	.013*	.139	0.21	1, 29	.653	.007	8.47	1, 29	.007*	.226
positive feelings	SAM vs GAM	4.40	2, 58	.017	.132	0.01	1, 29	.928	.000	5.15	1, 29	.031	.151
	SAM vs NM	7.66	2, 58	.001*	.209	0.30	1, 29	.587	.010	16.71	1, 29	<.001*	.365
valence	SAM vs GAM	9.07	2, 58	<.001*	.238	2.06	1, 29	.162	.066	11.79	1, 29	.002*	.289
	SAM vs NM	7.68	2, 58	.001*	.209	0.80	1, 29	.380	.027	8.06	1, 29	.008*	.217
psychophysiology													
corrugator supercilii	SAM vs GAM	2.75	2, 50	.073	.099	0.62	1, 26	.438	.023	5.03	1, 25	.034*	.167
	SAM vs NM	5.17	2, 44	.016*	.190	3.97	1, 23	.058	.147	3.48	1, 22	.075	.137

Note. Post-hoc tests of analysis of differences in emotional responses to the socially aversive compared to the generally aversive memory condition (SAM vs GAM) and the socially aversive compared to the neutral memory condition (SAM vs NM) between the three timepoints of the experimental session (T1 = baseline; T2 = after the control intervention; T3 = after Imagery Rescripting), as well as effects of the control intervention (T1 vs T2) and Imagery Rescripting (T2 vs T3). *F*-statistics of interaction effects, degrees of freedom (*df*), significance level (*p*) and effect sizes (*partial η²*). Bonferroni-correction for multiple testing for subjective feelings.

Figure 3. Mean differences in subjective feelings and psychophysiology between the interventions (T1 vs T2; T2 vs T3) for each memory condition



Note. Mean difference scores of T2 minus T1 (control intervention) and T3 minus T2 (Imagery Rescripting) for each of the three memory conditions. SAM = socially aversive memory; GAM = generally aversive memory; NM = neutral memory; ECG = electrocardiogram, IBI = interbeat intervals; SCRs = skin conductance responses. Error bars represent standard errors.

significantly higher and positive feelings and valence significantly lower for both aversive memories compared to the neutral memory, which is in line with the hypotheses (see Supplementary Table 2, Supplementary Figure 1). No significant differences were found between the socially aversive compared to the generally aversive memory.

Psychophysiology. Activity of the corrugator supercilii differed significantly between the memory conditions (see Table 2, Supplementary Table 1). Compared to the neutral memory, activity of the corrugator supercilii was significantly higher for both aversive memories, which is consistent with the hypotheses (see Supplementary Table 2). No differences were found for the other psychophysiological parameters.

Short-Term Intervention Effects on the Socially Aversive Memory

Subjective Feelings.

Interventions Effects (T1 vs T2 vs T3). Repeated-measure ANOVAs (3 timepoints × 3 memory conditions) were conducted to analyze effects of ImRs on the socially aversive memory compared to the control intervention and both control memories (which were not rescripted). Analyses revealed significant timepoint × memory condition interaction effects for negative feelings, positive feelings and valence, while no significant differences were found for arousal (see Supplementary Table 3, for descriptive statistics see Supplementary Table 1). To further investigate these effects, additional repeated-measure ANOVAs were conducted for comparison of the socially aversive memory with each control memory separately (3 timepoints × 2 memory conditions), also revealing significant effects for negative feelings, positive feelings (only marginally significant for comparison of the socially aversive compared to the generally aversive memory) and valence (see Table 3, Figure 2, Figure 3). Post-hoc analyses investigating effects of both interventions separately are reported in the following paragraphs.

Effects of Control Intervention (T1 vs T2). To specifically investigate effects of the control intervention (T1 vs T2), repeated-measure ANOVAs (2 timepoints × 2 memory conditions) were conducted. Analyses revealed no significant interaction effects for subjective feelings between the socially aversive memory and both control memories separately, which is in line with the hypotheses (see Table 3).

Effects of ImRs (T2 vs T3). Effects of ImRs (T2 vs T3) were also analyzed using repeated-measure ANOVAs for comparison of the socially aversive memory with the general aversive and neutral memory, respectively (2 timepoints × 2 memory conditions). Compared to both control memories separately, negative feelings were significantly reduced for the socially aversive memory from before to after ImRs,

while positive feelings (for comparison of the socially aversive vs generally aversive memory only marginally significant) and valence were significantly increased (see Table 3). Post-hoc analyses of effects on the socially aversive memory revealed hypotheses-confirming effects: a significant reduction in negative feelings ($t(29) = 4.49$, $p < .001$, *Cohen's d* = 0.820) and significant increases in positive feelings ($t(29) = -4.29$, $p < .001$, *Cohen's d* = -0.783) and valence ($t(29) = -4.98$, $p < .001$, *Cohen's d* = -0.909) from before to after ImRs. No significant changes were found for the generally aversive memory (negative feelings: $t(29) = -0.11$, $p = .914$, *Cohen's d* = - 0.020; positive feelings: $t(29) = -1.66$, $p = .108$, *Cohen's d* = -0.303 ; valence: $t(29) = -0.47$, $p = .639$, *Cohen's d* = 0.086) and the neutral memory (negative feelings: $t(29) = 0.95$, $p = .351$, *Cohen's d* = 0.173; positive feelings: $t(29) = -0.28$, $p = .778$, *Cohen's d* = -0.051; valence: $t(29) = -0.19$, $p = .851$, *Cohen's d* = -0.035).

Comparison Between Interventions (T2-T1 vs T3-T2). To examine differences in effects of the control intervention compared with the ImRs session, difference scores of the socially aversive memory minus the generally aversive memory and the socially aversive memory minus the neutral memory were compared between T2 minus T1 (control intervention) vs T3 minus T2 (ImRs) for negative feelings, positive feelings and valence. Analyses revealed that ImRs compared to the control intervention resulted in a marginally significant stronger decrease in negative feelings for the socially aversive memory compared to the generally aversive memory ($t(29) = 2.02$, $p = .053$, *Cohen's d* = 0.369), but not to the neutral memory ($t(29) = 1.05$, $p =. 304$, *Cohen's d* = 0.192). In comparison to the neutral (but not the generally aversive) memory, positive feelings were significantly stronger increased for the socially aversive memory from before to after ImRs compared to the control intervention (social vs neutral memory: $t(29) = -2.99$, $p = .006$, *Cohen's d* = 0.546; social vs generally aversive memory: $t(29) = -1.51$, $p = .141$, *Cohen's d* = -0.276). No significant differences between the interventions were found for valence (social vs generally aversive memory: $t(29) = -1.29$, $p = .208$, *Cohen's d* = 0.236; social vs neutral memory: $t(29) = -0.91$, $p = .372$, *Cohen's d* = -0.166). Post-hoc t-tests of the socially aversive memory revealed no significant differences in changes of negative feelings between both interventions ($t(29) = 1.51$, $p = .143$, *Cohen's d* = 0.276) and also no significant changes between the interventions for the generally aversive memory ($t(29) = -0.57$, $p = .576$, *Cohen's d* = -0.104). Regarding positive feelings, post-hoc *t*-tests revealed that ImRs compared to the control intervention resulted in a significantly stronger increase ($t(29) = -3.23$, $p = .003$, *Cohen's d* = -0.590) for the socially aversive memory, while no significant differences between the interventions were found for the neutral memory ($t(29) = 0.35$, $p = .730$, *Cohen's d* = 0.064).

Psychophysiology.

Intervention Effects (T1 vs T2 vs T3). Repeated-measure ANOVAs (3 timepoints × 3 memory conditions) were conducted to analyze effects of ImRs on psychophysiological responses to the socially aversive memory in comparison to the control intervention and both control memories. As hypothesized, significant timepoint × memory interaction effects were found for activity of the corrugator supercilii (see Supplementary Table 3, for descriptive statistics see Supplementary Table 1), which remained significant for comparison of the socially aversive memory with each control memory separately over the three timepoints (for comparison of the socially aversive vs generally aversive memory only marginally significant, see Table 3, Figure 2, Figure 3). No significant effects were found for ECG, SCRs and activity of the zygomaticus major, contradicting hypotheses.

Effects of the Control Intervention (T1 vs T2). To analyze effects of the control intervention (T1 vs T2) separately, repeated-measure ANOVAs (2 timepoints × 2 memory conditions) were conducted. Changes in activity of the corrugator supercilii from before to directly after the control intervention did not differ significantly between the socially aversive compared to the generally aversive memory, but marginally significant compared to the neutral memory (see Table 3). Post-hoc *t*-tests of effects specifically on the socially aversive memory however revealed no significant changes in activity of the corrugator supercilii from before to directly after the control intervention ($t(23) = 1.47$, $p = .155$, *Cohen's d* = 0.307), but a marginally significant increase in activation for the neutral memory ($t(23) = -1.96$, $p = .062$, *Cohen's d* = 0.400).

Effects of ImRs (T2 vs T3). Effects of ImRs (T2 vs T3) on activity of the corrugator supercilii were also analyzed using repeated-measure ANOVAs (2 timepoints × 2 memory conditions). Activity of the corrugator supercilii was significantly stronger reduced for the socially aversive memory compared to each control memory (for comparison with the neutral memory only marginally significant) from before to directly after ImRs (see Table 3). Post-hoc *t*-tests of the socially aversive memory revealed a significant reduction in activity of the corrugator supercilii ($t(26) = 2.88$, $p = .008$, *Cohen's d* = 0.554), while no significant changes were found for the generally aversive memory ($t(25) = -0.20$, $p = .844$, *Cohen's d* = 0.039) and neutral memory ($t(22) = 0.09$, $p = .927$, *Cohen's d* = 0.019), which is in line with the hypotheses.

Table 4. Analysis of follow-up effects (T2 vs T4) on subjective feelings

	SAM vs GAM vs NM			*SAM vs GAM*			*SAM vs NM*		
	F	*p*	*partial η²*	*F*	*p*	*partial η²*	*F*	*p*	*partial η²*
negative feelings	8.67	.001*	.257	9.60	.005*	.277	12.62	.002*	.335
positive feelings	7.79	.001*	.238	0.98	.332	.038	15.49	.001*	.383
valence	9.85	<.001*	.283	3.98	.057	.137	55.11	<.001*	.688
arousal	4.32	.019	.147	-	-	-	-	-	-

Note. SAM = socially aversive memory, GAM = generally aversive memory, NM = neutral memory. *F*-statistcs, significance level (*p*) and effect size (*partial η²*). Degrees of freedom (*df*) for SAM vs GAM vs NM = 2, 50; *df* for SAM vs GAM = 1, 25; *df* for SAM vs NM = 1, 25.* $p < .05$. Bonferroni correction for multiple testing.

Comparison Between Interventions (T2-T1 vs T3-T2). Differences in effects of the control intervention and the ImRs session were analyzed by conducting difference scores of the socially aversive memory minus the generally aversive memory and the socially aversive memory minus the neutral memory, which were compared between T2 minus T1 (control intervention) vs T3 minus T2 (ImRs). No significant differences between the interventions were found for activity of the corrugator supercilii for the socially aversive memory compared to the neutral memory ($t(22) = -0.20$, $p = .841$, *Cohen's d* = -0.042), however marginally significant differences compared to the generally aversive memory ($t(22) = 2.07$, $p = .050$, *Cohen's d* = 0.432), partially confirming the hypotheses. Post-hoc t-tests revealed no significant differences in changes in activity of the corrugator supercilii between the interventions for the socially aversive memory ($t(22) = 0.86$, $p = .400$, *Cohen's d* = 0.179) and the generally aversive memory ($t(22) = -1.25$, $p = .223$, *Cohen's d* = 0.261).

Further Analyses.

Cognitions. In addition to emotional responses (which were the main focus of this study), effects of ImRs on several cognitions were analyzed. Consistent effects were only found for empowerment, which was significantly increased during ImRs for the socially aversive memory ($t(29) = -4.75$, $p < .001$, *Cohen's d* = -0.867), while no effects were found for the generally aversive memory ($t(29) = -1.58$, $p = .125$, *Cohen's d* = -0.288). Moreover, empowerment for the neutral memory was significantly reduced ($t(29) = 2.28$, $p = .030$, *Cohen's d* = 0.416). Effects of ImRs on empowerment of the socially aversive memory were significantly stronger compared to both control memories and the control intervention (see Supplementary Tables 4 – 6).

Posttraumatic Memory Characteristics. Besides, we also investigated ImRs effects on memory disorganization and re-experiencing. Memory disorganization of the socially aversive memory was reduced significantly from before to after ImRs ($t(29) = 2.86$, $p = .008$, *Cohen's d* = 0.522), while disorganization of the generally aversive memory ($t(29) = -1.87$, $p = .072$, *Cohen's d* = -0.341) and neutral memory ($t(29) = -3.12$, $p = .004$, *Cohen's d* = -0.570) were (marginally) significantly increased. ImRs effects on disorganization of the socially aversive memory were significantly stronger compared to both control memories and the control intervention (see Supplementary Tables 4 – 6). ImRs effects on memory re-experiencing, however, did not differ significantly for the socially aversive memory compared to both control memories and the control intervention.

One-Week Follow-up Intervention Effects on the Socially Aversive Memory

As data at the one-week follow-up were assessed online, no data of the imagination task are available for this timepoint. Data regarding subjective feelings presented in the following are derived from a questionnaire on memory appraisal ratings resembling the ratings of subjective feelings of the imagination task.

Subjective Feelings. To analyze effects of ImRs one week after the intervention (T2 vs T4), repeated-measure ANOVAs (2 timepoints × 3 memory conditions) were conducted for negative feelings, positive feelings, valence and arousal. Interaction effects revealed significant differences in changes from before ImRs (T2) to one-week follow-up (T4) for negative feelings, positive feelings and valence for the socially aversive compared to both control memories (see Table 4). To further specify these effects additional repeated-measure ANOVAs (2 timepoints × 2 memory conditions) were conducted for the socially aversive memory compared to each control memory separately. Analyses revealed that the socially aversive memory compared to both control memories separately differed significantly in negative feelings, positive

feelings (only socially aversive vs neutral) and valence (only socially aversive vs neutral) from before ImRs compared to one-week follow-up (see Table 4). Post-hoc t-tests of the socially aversive memory revealed hypotheses-confirming effects: a significant reduction in negative feelings ($t(25) = 6.18$, $p < .001$, *Cohen's d* = 1.212) and a significant increase in valence ($t(25) = -4.37$, $p < .001$, *Cohen's d* = -0.857) from before ImRs to one-week follow-up (no effects for positive feelings: $t(25) = -1.57$, $p = .130$, *Cohen's d* = -0.308). No effects were found for negative feelings for the neutral ($t(25) = 1.25$, $p = .224$, *Cohen's d* = 0.245) and the generally aversive memory ($t(25) = 2.47$, $p = .021$, *Cohen's d* = 0.484), while positive feelings ($t(25) = 2.63$, $p = .014$, *Cohen's d* = 0.516) and valence ($t(25) = 1.07$, $p = .295$, *Cohen's d* = 0.210) were significantly decreased for the neutral memory.

Comparison Between Interventions (T2-T1 vs T4-T2). To analyze differences between short-term effects of the control intervention and one-week follow-up effects of ImRs, difference scores for negative feelings and valence (control intervention: T2 - T1; one-week follow-up: T4 - T2) were calculated for each memory condition. No differences between short-term effects of the control intervention and one-week follow-up effects were found for negative feelings (socially aversive vs generally aversive: $t(25) = 1.48$, $p = .152$, *Cohen's d* = 0.290; socially aversive vs neutral: $t(25) = 1.06$, $p = .300$, *Cohen's d* = 0.208), but for valence, which was (marginally) significantly stronger increased for the socially aversive compared to the generally aversive ($t(25) = -1.80$, $p = .085$, *Cohen's d* = 0.353) and to the neutral memory ($t(25) = -3.04$, $p = .005$, *Cohen's d* = 0.596). Post-hoc analyses of the socially aversive memory revealed that valence ($t(25) = -2.55$, $p = .017$, *Cohen's d* = 0.500) was significantly stronger increased from before ImRs to one-week follow-up for the socially aversive memory, while no effects were found for the generally aversive memory ($t(25) = -0.72$, $p = .478$, *Cohen's d* = 0.141) and the neutral memory ($t(25) = 1.41$, $p = .172$, *Cohen's d* = 0.277).

Further Analyses.

Cognitions. Similar to short-term effects, consistent effects for cognitions at one-week follow-up (T2 vs T4) were only found for empowerment, which was significantly increased from before ImRs to one-week follow-up for the socially aversive memory ($t(25) = -4.27$, $p < .001$, *Cohen's d* = 0.837), while no effects were found for the generally aversive memory ($t(25) = -1.55$, $p = .133$, *Cohen's d* = 0.304) and the neutral memory ($t(25) = 1.62$, $p = .118$, *Cohen's d* = 0.318). Effects from before ImRs to one-week follow-up on empowerment regarding the socially aversiv memory were significantly stronger compared to both control memories (see Supplementary Table 7) and compared to short-term effects (T1 vs T2) of the control intervention ($t(25) = -3.02$, $p = .006$, *Cohen's d* = 0.592).

Posttraumatic Memory Characteristics. Memory disorganization was reduced significantly from before ImRs to one-week follow-up (T2 vs T4) for the socially aversive memory ($t(25) = 2.90$, $p = .008$, *Cohen's d* = 0.569), while memory disorganization of the generally aversive memory ($t(25) = -2.21$, $p = .037$, *Cohen's d* = 0.433) and the neutral memory ($t(25) = -3.31$, $p = .003$, *Cohen's d* = 0.649) was significantly increased. Disorganization of the socially aversive memory was significantly stronger reduced for the socially aversive memory from before ImRs to one-week follow-up compared to both control memories (see Supplementary Table 7) and marginally significant compared to short-term effects of the control intervention (T1 vs T2; $t(25) = 1.93$, $p = .065$, *Cohen's d* = 0.379). ImRs effects on memory re-experiencing did not differ significantly for the socially aversive memory compared to both control memories from before ImRs to one-week follow-up.

Fear of Negative Evaluation and Social Anxiety.

Effects of the Experimental Session on Fear of Negative Evaluation and Social Anxiety. To investigate effects of the experimental session on fear of negative evaluation and social anxiety, paired-*t*-tests (T1 vs T4) were conducted. As hypothesized, we found a significant reduction in fear of negative evaluation ($t(25) = 2.40$, $p = .024$; *Cohen's d* = 0.471) from before to one week after the experimental session (*M(SD)* T1: 48.27 (10.16) vs T4: 45.08 (10.62)). No effects, however, were found for social anxiety ($t(26) = 1.24$, $p = .226$; *Cohen's d* = 0.239; *M(SD)* T1: 15.42 (12.88) vs T4: 13.54 (12.69)).

Effects of Fear of Negative Evaluation and Social Anxiety on Memory-Related Outcomes. To analyze associations between symptom severity (fear of negative evaluation, social anxiety) and ImRs effects on memory-related outcomes (subjective feelings, psychophysiology, posttraumatic memory characteristics, cognitions), exploratory correlational analyses were conducted between fear of negative evaluation and social anxiety (T1) and changes in memory-related outcomes from before to after ImRs (T3 - T2) for the socially aversive memory. Analyses revealed significant positive correlations between social anxiety and an increase in valence ($r = .482$, $p = .007$) and marginally significant in empowerment ($r = .360$, $p = .071$), as well as a decrease in SCRs ($r = -.361$, $p = .099$), indicating greater effects of ImRs for participants with increased levels of social anxiety (all other variables: $p > .05$ after Bonferroni-Holm correction). No significant correlations were found for fear of negative evaluation.

Discussion

The aim of this study was to examine if ImRs of a socially aversive memory has any effect on emotional responses (subjective, psychophysiological) during imagination of the rescripted memory. An adapted version of an imagination task (McTeague et al., 2009; Sansen et al.; 2015) proved to be valid in eliciting emotional responses during voluntary recall of aversive memories compared to a neutral memory. Results indeed showed effects of ImRs on emotional responses specifically to the rescripted socially aversive memory: an increase in positive feelings and valence, as well as a reduction in negative feelings, and activity of the corrugator supercilii related to the socially aversive memory. However, ImRs did not have an additional effect on negative feelings and valence but on positive feelings and activity of the corrugator supercilii (only compared to the generally aversive memory) when compared to the preceding active control intervention. Concerning memory-related cognitions and posttraumatic memory characteristics, we found a significant increase in empowerment, as well as a reduction in disorganization after ImRs compared to the control intervention, specifically regarding the socially aversive memory. At one-week follow-up, negative feelings were still reduced, and valence still increased significantly and participants indicated increased empowerment and decreased disorganization specifically regarding the socially aversive memory. Correlational analyses revealed (marginally) significant associations between social anxiety and ImRs effects in some variables, indicating more benefits for participants with increased levels of social anxiety. In addition, levels of fear of negative evaluation (but not social anxiety) were reduced significantly one week after ImRs.

This study was the first using an imagination task to examine effects of ImRs on psychophysiological correlates of a rescripted socially aversive memory. At baseline, we found the expected differences in subjective emotional responses to the memories also coinciding with stronger activity of the corrugator supercilii during imagination of the socially aversive memory in comparison to the neutral memory. This is in accordance with findings of heightened activation of the corrugator supercilii during imagination of a socially aversive situation in both, healthy controls and SAD patients (McTeague et al., 2009). No differences in activity of the zygomaticus major, HR and SCRs during imagination of the socially aversive memory compared to the neutral memory were found in the current study. Previous findings in healthy participants (examined as a control group for SAD) showed no heightened HR and SCL to standardized socially aversive scripts, but to personal fear scripts (not socially aversive) (Cuthbert et al., 2003; McTeague et al., 2009). In this study we used an autobiographical socially aversive memory, which might have not induced as strong negative emotions in healthy participants as a personal fear memory or as in patients with SAD.

In addition to these findings at baseline, our results showed that ImRs led to changes in the emotional responses (more positive, less negative) to the socially aversive memory. Results of self-report measures coincide with psychophysiological measures, showing that ImRs led to a decrease in activation of the corrugator supercilii during imagination of the socially aversive memory compared to the generally aversive memory. These findings are in line with studies in SAD patients, reporting reduced distress related to the socially aversive memory due to ImRs (e.g., Lee & Kwon, 2013; Reimer & Moscovitch, 2015; Romano et al., 2020; Wild et al., 2007). However, effects of ImRs on negative feelings and valence did not go beyond effects of the preceding active control intervention reducing the interpretability of these findings. As participants also took a closer look at the socially aversive memory in the control intervention and were guided by an experimenter, this may also have had small effects on the measures. Simultaneously, a single session ImRs especially in healthy individuals might not produce large effects (for this, an intensification of the intervention [e.g., multiple sessions] might be more effective). At one-week follow-up (compared to pre-ImRs) negative feelings regarding the socially aversive memory were still reduced and valence still increased significantly, also compared to both control memories, indicating intervention specific effects on the measures. However, one-week follow-up effects of negative feelings did again not go beyond short-term effects of the control intervention. In addition, results of follow-up analyses cannot be compared one to one to the results of the experimental session because different data collection methods were used (imagination task vs memory appraisal ratings). To sum up, even in a healthy sample, ImRs led to changes in the emotional response to a socially aversive memory. However, in some cases, these effects did not go beyond the effects of a preceding active control intervention which might be grounded in reduced distress in response to the socially aversive memory, as well as (naturally) lower SAD symptoms (e.g., physiological activation) in healthy individuals compared to SAD patients (DSM-5; American Psychiatric Association, 2013). Increased ImRs effects for participants with higher levels of social anxiety ([marginally] significant correlations for some variables) point towards potentially increased benefits

for individuals with increased social anxiety or even SAD.

ImRs also led to a decrease (also at one-week follow-up) in memory disorganization, as well as an increase in empowerment specific for the socially aversive memory. During the process of ImRs participants relive their memory for several times which might enhance factual memory, as well as its contextualization and thus reduce memory disorganization (e.g., Hagenaars & Arntz, 2012). Effects concerning empowerment are in line with previous results indicating that ImRs in nightmare disorder works through increased feelings of mastery (Kunze et al., 2019). The intervention highlights participants' development from feeling exposed to the situation as their younger self to actively intervene as an adult. No consistent effects were found for other memory-related cognitions despite empowerment and memory re-experiencing, which might also be grounded in our healthy sample.

This study has several limitations. First, we used a within-subject design which does not allow to distinguish between effects of ImRs and the control intervention especially regarding the effects on fear of negative evaluation and social anxiety measures one week after the experiment. The control intervention can, however, similar to previous studies (e.g., Norton & Abbott, 2016; Wild et al., 2007, 2008), also be regarded as an additional preparation for the subsequent ImRs session. Second, we cannot rule out potential sequence effects, as we always applied ImRs after the control intervention. We did not use a cross-over design to rule out expectable carry-over effects of ImRs on the control intervention. However, stronger increase in positive feelings and stronger decrease in activity of the corrugator supercilii after ImRs compared to the control intervention indicate additional effects going beyond habituation. To explore the specificity of the intervention on the rescripted memory, we added the generally aversive memory and the neutral memory as control conditions. Future studies should employ a between-subjects design with one group receiving one session ImRs and the other group a control intervention. Third, we cannot make a statement on mechanisms of change in ImRs as our study design does not meet the requirements for analysis of a causal mediation model (Kazdin, 2007). Finally, ImRs in healthy participants might work differently than in SAD patients and thus we cannot be certain whether the presented results can be generalized to a patient population. Analyses of the effects of social anxiety point towards potential differences in efficacy of the intervention (for some responses to the memory), with greater benefit for participants with increased social anxiety. Hence, replications in patient samples would be desirable.

Conclusions

This is the first study to use an imagination task to examine effects of ImRs on subjective and physiological emotional responses to a socially aversive memory. Results indicate that ImRs affects the emotional processing of the memory and thus further support UCS revaluation theory (Arntz, 2011, 2012; Davey, 1989), indicating that ImRs has a direct effect on the emotional meaning of the memory. However, more information, especially about physiological processes during ImRs in patients with SAD, are needed to better understand its underlying mechanisms.

Additional Information

Supplementary Materials

Supplementary materials for this article can be viewed here: https://osf.io/eb6zp

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Conflict of Interest

The authors have no conflicts of interest to disclose.

Ethical Approval

The study protocol (2018-0036) was approved on 11/15/2018 by the local ethics committee of the Department 06 Psychology and
Sport Sciences of the Justus Liebig University Giessen.

Data Availability

Data not available.

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