



Mental threat rehearsal increases fear generalization

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ABSTRACT

Background and objectives: Fear generalization to harmless stimuli characterizes anxiety-related disorders, but much remains unknown about its determinants. Based on studies showing that mental imagery of threat can increase conditioned fear responding, we tested whether it also facilitates fear generalization, and whether threat inflation moderates this effect.

Methods: In a fear conditioning study, 120 participants first completed an acquisition phase, in which one of two pictures was followed by an aversive sound (human scream). Then, the sound was presented 11 times at an increasing (threat inflation) or constant volume (no threat inflation). Finally, a generalization stimulus was presented, and some participants were asked to imagine the last sound (threat rehearsal) and others were not (no threat rehearsal).

Results: Bayesian informative hypotheses tests indicated that imagery-based threat rehearsal increased generalization of threat expectancy, and, combined with threat inflation, it also resulted in stronger generalized distress. **Limitations:** due to the absence of a test phase, it is unclear whether our effects would transfer to other GSs and whether they would persist beyond the manipulation phase.

Conclusions: Mental imagery of threat may put individuals at risk for fear generalization. Future studies should examine whether modulating imagery may prevent clinical anxiety.

1. Introduction

Fear is vital to survival. Yet aversive experiences are never identical, so we must generalize the fear we learned for a particular stimulus to future encounters that resemble the original event to a sufficient degree (Asok, Kandel, & Rayman, 2019). This allows us to respond quickly to novel relevant stimuli (Dunsmoor, Mitroff, & LaBar, 2009). However, overgeneralization of fear to harmless stimuli or situations is a hallmark of anxiety-related disorders (American Psychiatric Association, 2013). For example, if a child has learned to fear a white rat, it can also exhibit fear of a white rabbit or a fur coat (Watson & Rayner, 1920). Therefore, an important theoretical and clinical question is how fear generalizes to harmless stimuli.

Fear generalization can be modeled in the lab with fear conditioning paradigms (Dymond, Dunsmoor, Vervliet, Roche, & Hermans, 2015). These paradigms usually start with a fear acquisition phase in which an innocuous stimulus, such as a picture of a neutral face, is repeatedly followed by a threat, such as a loud scream (i.e., unconditioned stimulus; US). After several pairings, the picture has become a conditioned stimulus (CS+) that typically excites strong subjective and physiological fear

responses. In a subsequent fear generalization phase, one or more pictures that are perceptually or conceptually similar to the CS+ (i.e., generalization stimuli; GSs), such as morphs of different faces (Leer et al., 2017), are presented without the US. GSs that resemble the CS+ generally elicit fear responses, even though they have never been paired with the threatening stimulus (e.g., Dymond et al., 2015). Notably, during this phase, patients with anxiety-related disorders typically show elevated fear generalization (i.e., also to GSs that bear less similarity to the CS+), relative to healthy comparison groups (e.g., Kaczurkin et al., 2017; Lissek et al., 2010), which underscores the paradigm's validity.

Research has shown that fear acquisition and generalization are complex phenomena that go beyond the mere pairing of stimuli (Asok et al., 2019; Dymond et al., 2015). For example, they also depend on verbal instructions (Mertens, Boddez, Sevenster, Engelhard, & De Houwer, 2018), abstract processing (Van Lier, Vervliet, Vanbrabant, Lenaert, & Raes, 2014, 2015), observational learning (Cameron, Schlund, & Dymond, 2015), and inductive reasoning (Dunsmoor & Murphy, 2015). Another way in which fear generalization could be modulated is by mental imagery: the experience of "seeing with the mind's eye, or hearing with the mind's ear etc." (Holmes & Mathews,

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2010; Kosslyn, Ganis, & Thompson, 2001). Mental imagery can be considered as a weak form of sensory perception (Pearson, 2019), sharing brain regions involved in actual perception (Ganis, Thompson, & Kosslyn, 2004). It has functions, such as revisiting the past to learn from consequences, or projecting oneself in a future situation to adjust decision-making strategies and behavior (Bulley, Henry, & Suddendorf, 2017; Libby, Shaeffer, Eibach, & Slemmer, 2007; Schacter & Addis, 2007). Yet, aversive mental imagery (e.g., vivid involuntary images of threat) may be dysfunctional and is considered a maintaining factor of clinical anxiety (Berntsen, 2010; Brewin, Gregory, Lipton, & Burgess, 2010; Holmes & Mathews, 2010). Clinical and lab studies have found compelling evidence that mental imagery of threat can enhance fear acquisition and impede extinction learning (e.g., Hirsch, Clark, Mathews, & Williams, 2003, 2004; Mertens, Krypotos, & Engelhard, 2020). For example, Joos, Vansteenwegen, and Hermans (2012a, 2012b) demonstrated that individuals who were asked to repeatedly imagine the CS+/US association after acquisition showed more elevated fear responses to the CS+ than individuals who were not asked to do this. Reversely, mental imagery of *safety learning* may promote extinction learning. In a study by McGlade and Craske (2021), students with fear of spiders completed two exposure training sessions with a tarantula in a terrarium. On three separate days after each exposure session, participants in the “exposure rehearsal” group were asked to retrieve their exposure memory and rehearse how their negative outcome expectancy had been violated. They were also asked to relive their experience with the spider. Participants in the “control rehearsal” group were asked to rehearse the last time they were in class. Results showed that, relative to the control rehearsal group, the exposure rehearsal group showed more substantial symptom reductions and less subjective distress before and less avoidance during a behavioral approach test.

Thus far, to our knowledge, only one study has examined whether mental imagery of threat facilitates fear generalization. Krypotos, Mertens, Leer, and Engelhard (2020) tested whether repeatedly imagining a CS-/US association amplifies the generalization of fear and avoidance from a CS+ to CS-. In the acquisition phase, one colored square (CS+) was followed by a shock, and two differently colored squares (CS-) were not. During a subsequent rehearsal phase, participants were asked to mentally rehearse “as vividly as possible” one of the CSs-together with either the shock (“shock group”) or a neutral tone (“tone group”). Results showed that the “shock group” exhibited higher shock expectancy, subjective fear, and avoidance responses to that CS-, compared to the “tone group”. They suggest that repeated mental imagery of the CS-/US association created a new association between a safe and an aversive stimulus. It remains unknown whether imagery-based threat rehearsal facilitates fear generalization toward a novel stimulus.

Threat intensity is another important factor in fear acquisition that affects generalization of fear (e.g., Leer & Engelhard, 2015). For example, a fear conditioning study showed that individuals displayed more distinct fear generalization after a fear acquisition phase with a high relative to a low-intensity threat (Dunsmoor, Kroes, Braren, & Phelps, 2017). Moreover, anecdotal evidence from case studies suggests that individuals without an aversive conditioning experience may be more susceptible to developing anxiety symptoms when threat evaluation becomes more negative (i.e., threat inflation; Davey, de Jong, & Tallis, 1993). Several lab studies indeed demonstrated that threat inflation leads to increased conditioned fear (e.g., Hosoba, Iwanaga, & Seiwa, 2001; White & Davey, 1989). As far as we know, no lab studies have tested whether threat inflation may also increase fear generalization.

The current fear conditioning study had three aims. First, we aimed to examine whether mental rehearsal of threat in the presence of a novel (perceptually similar) GS would show increased threat expectancy and distress to this GS relative to no rehearsal. Second, we examined whether threat inflation would lead to increased threat expectancy and distress to the GS relative to no threat inflation. Third, we tested whether mental rehearsal combined with threat inflation would lead to higher

threat expectancy and distress to this GS, relative to the other three conditions.

2. Methods

2.1. Participants

A total of 128 Dutch-speaking students aged between 18 and 30 were recruited via name University, Facebook, and Proefbunny.nl. Exclusion criteria were: visual impairment, color blindness, hearing problems, psychoactive medication, diagnosis of mental disorder, or neurological problems. Participants were randomly assigned (stratified for gender) to one of the four conditions: 1) threat rehearsal with threat inflation; 2) threat rehearsal without threat inflation; 3) no threat rehearsal with threat inflation; 4) no threat rehearsal without threat inflation. After participation, we excluded eight participants from analyses due to: unsuccessful fear learning ($n = 4$), familiarity with the stimuli and procedure ($n = 2$), non-adherence to instructions ($n = 1$), and an equipment failure ($n = 1$). The final sample comprised 120 participants (80 females and 40 males; mean age = 21.30, SD = 2.02). The study protocol was approved by the ethics committee of the Faculty of Social and Behavioral Sciences at name University (FETC16-054) and was carried out in accordance with the provisions of the World Medical Association Declaration of Helsinki. This study was preregistered (including a power analysis) on the Open Science Framework (INSERT link).

2.2. Stimuli

Conditioned stimuli (CSs) were a neutral female face and a neutral male face (387×511 pixels), which were selected from the Radboud Face database (Langner et al., 2010). They randomly served as CS+ or CS-. The generalization stimulus (GS) was a morph of the CS+ with another same-gender morph (using Abrosoft Fantamorph software); see Fig. S1 in the Supplemental Materials. The unconditioned stimulus (US) was a 2-s scream, which was presented binaurally at 60 dB during the acquisition phase.

2.3. Trial procedure

Each trial consisted of a 12-s CS or GS presentation in the middle of the computer screen on a black background. Participants were asked to rate threat expectancy during the first 4 s and distress during the following 4 s. Throughout the acquisition phase, the scream was presented 8 s after CS+ onset. CSs and GSs were presented in a pseudo-random order (i.e., a maximum of two consecutive presentations per phase). The 4 to 5-s inter-trial interval (ITI) was a black screen with a white fixation cross (Joos et al., 2012a).

2.4. Measures

2.4.1. Neuroticism scale of the Eysenck personality questionnaire (EPQ-N)

Neuroticism was measured with a validated Dutch translation of the EPQ-N (Eysenck & Eysenck, 1991; Sanderman, Arrindell, Ranchor, Eysenck, & Eysenck, 2012). This questionnaire consists of 22 questions (e.g., “Are you often troubled about feelings of guilt?”) that are answered on a dichotomous scale (0 = no, 1 = yes). Cronbach’s α was 0.82 in this study.

2.4.2. Anxiety sensitivity index (ASI)

Anxiety sensitivity was assessed with a validated Dutch translation of the ASI (Reiss, Peterson, Gursky, & McNally, 1986; Vujanovic, Arrindell, Bernstein, Norton, & Zvolensky, 2007). The scale has 16 items (e.g., “It scares me when my heart beats rapidly”) which are rated on a 5-point Likert scale, ranging from 0 (*very little*) to 4 (*very much*). Cronbach’s α was 0.78 in this study.

2.4.3. Plymouth sensory imagery questionnaire (PsiQ)

The vividness of mental imagery was assessed with a self-translated Dutch version of the PsiQ (Andrade, May, Deeproose, Baugh, & Ganis, 2014). The 21-item scale contains seven modalities of imagery (visual, audio, taste, touch, smell, emotions, and bodily sensations) that are measured with three items (e.g., “Imagine the sound of a car horn”). Items are rated on an 11-point Likert scale ranging from 0 (*no image at all*) to 10 (*as vivid as real life*). Cronbach’s α was 0.90 in this study.

2.4.4. Threat expectancy

Participants rated threat expectancy on a visual analog scale (VAS) with three anchors: 0 (*certainly no scream*), 50 (*uncertain*), and 100 (*certainly a scream*).

2.4.5. Distress

Participants indicated their distress level (“How distressed do you feel at this moment?”) on a visual analog scale (VAS) that ranged from 0 (*not distressed at all*) to 100 (*very distressed*).

2.4.6. Post-experimental questions





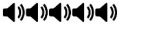





2.4.6.1. Manipulation check for threat rehearsal. Participants were asked to rate on a binary scale whether they rehearsed the US during the GS in the rehearsal phase (“Did you imagine the scream when you saw this picture?” 1 = yes, 2 = no). If they answered yes, they were asked to indicate the frequency, vividness, and unpleasantness of their rehearsal. VASs ranged from 0 (frequency: *never*; vividness: *not at all vivid*; unpleasantness: *not at all unpleasant*) to 100 (frequency: *always*; vividness: *very vivid*; unpleasantness: *very unpleasant*).

2.4.6.2. Manipulation check for threat inflation. Following Leer and Engelhard (2015), participants were asked to indicate whether they thought the intensity of the scream had changed, using three answer options: 1 = no, the scream did not change in intensity, 2 = yes, the scream became louder, or 3 = yes, the scream became weaker. If their answer was “yes”, they were asked to indicate whether they had the impression that 1) the original scream was presented weaker/stronger, or that 2) at some point, another, new scream was presented. This was done to check whether participants updated their US representation or whether they perceived a new stimulus. US unpleasantness was also rated for the 60 dB and 100 dB scream (“How unpleasant was the last scream you heard?”) on a scale from 0 (*not unpleasant at all*) to 100 (*extremely unpleasant*).

2.5. Procedure

Table 1 provides an overview of the experimental procedure.

Table 1
Overview of experimental design.

Group	Habituation	Acquisition	Inflation	Rehearsal
Threat rehearsal + threat inflation	CS+ (2) CS- (2)	CS+  CS- (6)		 GS (6) CS- (6)
Threat rehearsal + no threat inflation	CS+ (2) CS- (2)	CS+  CS- (6)		 GS (6) CS- (6)
No threat rehearsal + threat inflation	CS+ (2) CS- (2)	CS+  CS- (6)		GS (6) CS- (6)
No threat rehearsal + no threat inflation	CS+ (2) CS- (2)	CS+  CS- (6)		GS (6) CS- (6)

Note. CS = conditioned stimulus; GS = generalization stimulus.

Participants entered the lab and first completed the habituation phase, in which the CS+ and CS- were presented twice. In the acquisition phase, there were six presentations of each CS, with a 100% reinforcement rate of the CS+ (see Jones & Davey, 1990). Next, in the threat inflation phase, there were 11 unsignaled scream presentations (with a 5-s inter scream interval) at the same volume (no threat inflation) or at an increasing volume (threat inflation; 60, 65, 70, 75, 80, 85, 90, 95, 100, 100, 100 dB). In the rehearsal phase, the GS and CS- were each presented six times. Half of the participants was instructed that, whenever they would see a male/female face (i.e., GS that was congruent with the gender of the CS+), they first had to complete the threat expectancy (4 s) and distress (4 s) ratings and then had to imagine the last scream they had heard (i.e., threat rehearsal). They were asked to imagine this scream and their reactions to it as vividly as possible (see Jones & Davey, 1990) until the face disappeared (i.e., for 4 s). The other half of the participants was not asked to rehearse the US during this phase (i.e., no threat rehearsal). Next, in the test phase, each CS and multiple GSs were presented. Data of this test phase could not be analyzed due to a technical problem, but this did not affect the analyses of the preregistered hypotheses regarding fear generalization during the rehearsal phase. Finally, participants were asked to complete the post-experimental questions and were thanked, debriefed, and remunerated.

2.6. Data-analysis

2.6.1. Randomization and manipulation checks

Four checks were carried out. First, to examine whether randomization was successful, we performed four one-way ANOVAs with Group (4: threat rehearsal with/without threat inflation and no threat rehearsal with/without threat inflation) as the independent variable and age, anxiety sensitivity scores, neuroticism scores, and mental imagery vividness scores as dependent variables. Second, to test whether the imagery-based threat rehearsal was successful, we conducted a Bayesian Contingency Tables Test with Group (2: threat rehearsal, no threat rehearsal) as the independent variable and the binary rehearsal question as the dependent variable. We also conducted three one-way ANOVAs with Group (2: threat rehearsal with/without threat inflation) as independent variable and frequency, vividness, and unpleasantness of US imagery as dependent variables. Third, to examine whether the threat inflation manipulation was successful, we conducted a Bayesian Contingency Tables Test with Group (US-inflation, no threat inflation) as the independent variable and the threat inflation question as the dependent variable. Finally, to examine whether differential acquisition occurred, we performed two mixed ANOVAs with Stimulus (2: CS+, CS-), Time (6: acquisition trials 1–6), and Group (4: threat rehearsal with/without threat inflation and no threat rehearsal with/without threat inflation) as the independent variables, and threat expectancy and distress as the dependent variables. Analyses were conducted within the Bayesian hypothesis testing framework using JASP (Version 0.14.1.0; default settings). Bayes factors (BFs) denote the likelihood of the data under one hypothesis versus another hypothesis. Bayesian inference allows quantifying evidence for the null hypothesis (Kryptos, Klugkist, & Engelhard, 2017; Wagenmakers, Marsman, et al., 2018). For example, $BF_{10} = 3$ indicates that the data are three times more likely under H1 than H0 (and vice versa for $BF_{10} = 0.33$; Wagenmakers, Love, et al., 2018). A commonly used benchmark is that BF_{10} between 1 and 3 indicates anecdotal evidence in favor of H1 relative to H0, values between 3 and 10 indicate moderate evidence, and values greater than 10 indicate strong evidence. Likewise, BFs₁₀ below 0.33 indicate evidence in favor of the null hypothesis (Wagenmakers, Love, et al., 2018).

2.6.2. Hypotheses testing

The relative evidence for three hypotheses was tested. Hypothesis 1 was that threat rehearsal, relative to no threat rehearsal, leads to higher threat expectancy and distress toward the GS in the rehearsal phase. Hypothesis 2 was that threat inflation, relative to no threat inflation,

results in higher threat expectancy and distress toward the GS in the rehearsal phase. Hypothesis 3 was that threat rehearsal combined with threat inflation, relative to the other three conditions would lead to higher threat expectancy and distress toward the GS in the rehearsal phase.

The BAYesian INformative hypotheses evaluation (BAIN) module in JASP (JASP Team, 2020) was used to analyze the means for each hypothesis. For example, if $BF_{12} = 3$ means that the data are three times more likely under H1 than H2. In this example, the mean expectancy or distress level towards the GS is higher in the rehearsal groups relative to the inflation groups.

The following alternative hypotheses were used as a reference. The fourth hypothesis was that threat rehearsal and/or threat inflation are superior to no threat rehearsal combined with no threat inflation. Finally, the fifth hypothesis was that all groups are similar. A two-step approach was used to test the hypotheses: the Bayes Factor was calculated for each hypothesis relative to its complement and the hypothesis with the highest Bayes Factor was compared to all other hypotheses. Tables 2 and 3 report the formulas and descriptions of hypotheses.

2.7. Deviations from preregistration

There were three deviations from the preregistration for this study. First, because the data of the test phase could not be analyzed, we could we could not test the preregistered hypotheses about the test phase. Second, although the preregistration mentions using BIEMS software, we decided to use the more recently developed and advanced BAIN module instead, which yields similar Bayes Factors and is more robust to outliers and distributional assumptions (Hojtink, Mulder, van Lissa, & Gu, 2019). Third, the preregistration mentions analysis of all rehearsal trials, but BAIN and BIEMS do not allow testing mixed ANOVAs. We decided to examine group differences at the beginning (i.e., average of the first two trials) and the end of the rehearsal phase (i.e., average of the last two trials). We used the first two trials rather than the first trial only, because participants started with rehearsing *after* making their ratings on the first trial. Note that only analyzing the first and the last trial yielded similar results.

3. Results

3.1. Randomization checks

There was strong evidence that the groups were similar in age, and ASI, EPQ-N, and PsiQ scores ($BF_{s10} < 0.08$). This suggests successful

Table 2
Group Differences in Threat Expectancy to the GS at the Beginning and end of the Rehearsal Phase.

Hypothesis	Description	First trials	Last trials
1. $R + I = R + noI > noR + I = noR + noI$	Threat rehearsal leads to higher threat expectancy towards the GS than no threat rehearsal.	$BF_{1c} = 20.49$	$BF_{1c} = 56.48$
2. $R + I = noR + I > R + noI = noR + noI$	Threat inflation leads to higher threat expectancy towards the GS than no threat inflation.	$BF_{2c} = 9.13$	$BF_{2c} = 0.58$
3. $R + I > R + noI = noR + I = noR + noI$	Threat rehearsal combined with threat inflation leads to higher threat expectancy towards the GS than all other groups	$BF_{3c} = 6.73$	$BF_{3c} = 1.86$
4. $R + I = R + noI = noR + I > noR + noI$	Threat rehearsal and/or threat inflation lead to higher threat expectancy towards the GS.	$BF_{4c} = 73.27$	$BF_{4c} = 7.66$
5. $R + I = R + noI = noR + I = noR + noI$	Threat rehearsal and/or threat inflation do not affect threat expectancy towards the GS.	$BF_{5c} = 20.24$	$BF_{5c} = 4.51$

Note. BF = Bayes Factor; GS = generalization stimulus; I = Inflation; R = Rehearsal.

Table 3
Group differences in distress to the GS at the beginning and end of the rehearsal phase.

Hypothesis	Description	First trials	Last trials
1. $R + I = R + noI > noR + I = noR + noI$	Threat rehearsal leads to higher distress during the GS than no threat rehearsal.	$BF_{1c} = 0.01$	$B_{1c} = 0.05$
2. $R + I = noR + I > R + noI = noR + noI$	Threat inflation leads to higher distress during the GS than no threat inflation.	$BF_{2c} = 35.46$	$BF_{2c} = 8.85$
3. $R + I > R + noI = noR + I = noR + noI$	Threat rehearsal combined with threat inflation leads to higher distress during the GS than all other groups	$BF_{3c} = 2.29$	$BF_{3c} = 14.15$
4. $R + I = R + noI = noR + I > noR + noI$	Threat rehearsal and/or threat inflation lead to higher distress towards the GS.	$BF_{4c} = 0.12$	$BF_{4c} = 0.24$
5. $R + I = R + noI = noR + I = noR + noI$	Threat rehearsal and/or threat inflation do not affect distress during towards the GS.	$BF_{5c} = 0.02$	$BF_{5c} = 0.04$

Note. BF = Bayes Factor; GS = generalization stimulus; I = Inflation; R = Rehearsal.

randomization.

3.2. Manipulation checks

3.2.1. Threat rehearsal

More participants in the rehearsal groups (47/60; 78%) compared to the no-rehearsal groups (24/60; 40%) indicated that they had rehearsed the US during the GS in the rehearsal phase ($BF_{10} > 1000$). For the rehearsal groups, frequency ($BF_{10} = 0.33$) and vividness ($BF_{10} = 0.30$) of threat rehearsal ratings were similar, but for the rehearsal with threat inflation group, relative to the rehearsal without threat inflation group, unpleasantness of rehearsal ratings was higher ($BF_{10} = 12.73$). This suggests the rehearsal manipulation was successful.

3.2.2. Threat inflation

More participants in the inflation groups (43/60; 72%), compared to the no-inflation groups (8/60; 13%), reported that the scream had become louder during the experiment ($BF_{10} > 1000$), and most of them (39/43; 91%) correctly indicated that the original scream had become louder, while a minority (4/43; 9%) indicated that at some point, a new scream had been presented. All participants rated the 100-dB scream as more unpleasant ($M = 93.69$, $SD = 9.79$) than the 60-dB scream ($M = 44.44$, $SD = 26.50$; $BF_{10} > 1000$), with no group differences ($BF_{s10} < 0.21$). Together, these findings suggest that the threat inflation manipulation was successful.

3.2.3. Acquisition

Participants showed higher expectancies of the scream after CS+ than after CS- (Stimulus \times Time: $BF_{10} > 1000$; Stimulus: $BF_{10} > 1000$, and there were no group differences (all $BF_{s10} < 0.16$). They also had higher distress levels during CS+ than CS- presentations (main effect Stimulus: $BF_{10} > 1000$), which did not change over time (Stimulus \times Time: $BF_{10} = 0.01$). Groups did not differ in these effects (all $BF_{s10} < 0.25$). This indicates successful differential learning (see Fig. 1).

3.3. Hypotheses

3.3.1. Threat expectancy

For the first trials of the rehearsal phase, the strongest evidence was found for H4; see Table 2 for BF_{XC} values. So groups that engaged in threat rehearsal and/or underwent threat inflation had higher threat expectancy ratings in this phase, relative to the ‘no rehearsal and no inflation’ group. All other hypotheses were supported to a lesser extent. Informative hypothesis tests showed that the data were most likely

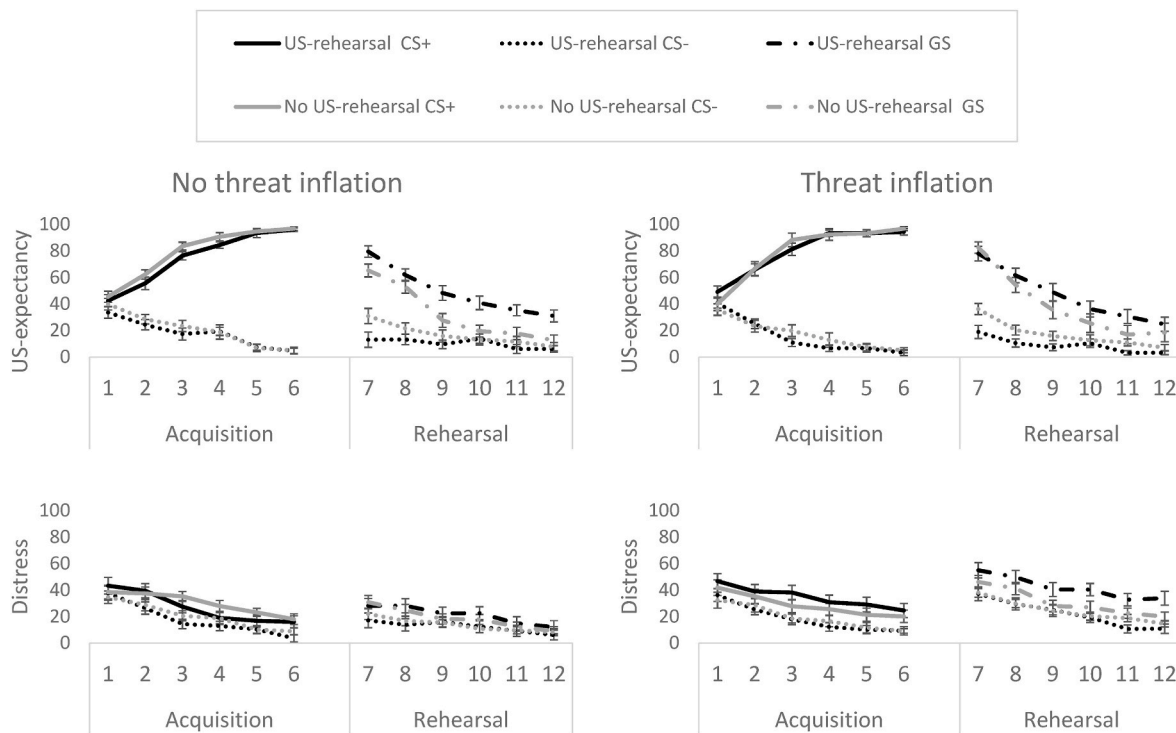


Fig. 1. Unconditioned stimulus (US) expectancy and distress ratings to conditioned (CSs) and generalization stimuli (GSs).

under H4 relative to any other hypothesis ($BF_{41} = 3.58$; $BF_{42} = 8.03$; $BF_{43} = 10.89$; $BF_{45} = 3.62$); see Table S1 for direct comparisons.

For the last trials of the rehearsal phase, the data were most likely under H1, followed by H4 and H5; see Table 2 for BF_{XC} values. This means that after threat rehearsal (with or without inflation), these threat expectancy ratings were higher. Tests of informative hypotheses showed that the data were more likely under H1 than under any alternative hypothesis ($BF_{12} = 98.15$; $BF_{13} = 30.37$; $BF_{14} = 7.37$; $BF_{15} = 12.52$); see Table S2 for other direct comparisons.

3.3.2. Distress

On the first trials of the rehearsal phase, the data were most likely under H2 (see Table 3). This means that threat inflation (with or without threat rehearsal) led to higher distress ratings than no threat inflation. Tests of informative hypotheses indicated that the data were more likely under H2 relative to any other hypothesis ($BF_{21} > 1000$; $BF_{23} = 15.50$; $BF_{24} = 291.39$; $BF_{25} > 1000$); see Table S3 for other comparisons.

At the end of the rehearsal phase, the data were most likely under H3 followed by H2 (see Table 3 for BF_{XC} values). Informative hypothesis tests (see Table S4) demonstrated that H3 received more support than H1 ($BF_{31} = 281.07$), H4 ($BF_{34} = 59.60$), and H5 ($BF_{35} = 409.10$). The evidence for H3 relative to H2 was inconclusive ($BF_{32} = 1.60$). This means that at the end of the rehearsal phase, rehearsal of the inflated US resulted in higher distress levels to the GS than all other groups. Yet, this hypothesis was not evidently stronger than the hypothesis stating that threat inflation (with or without rehearsal) results in higher distress to the GS than no threat inflation.

3.4. Exploratory analyses

To explore the specificity of threat rehearsal and inflation effects, we performed Bayesian Informative analyses on CS- (see Tables S5 and S6). For threat expectancy, there was no compelling evidence for any hypothesis at the start of the rehearsal phase (all $BF_{sXC} < 0.39$), but at the end of this phase, the strongest evidence was found for similarity between groups ($BF_{5c} = 33.87$; see Table S5). The data were most likely

under H5 relative to any other hypothesis (all $BF_{s5X} > 10.24$).

For distress ratings, there was strong evidence that ratings were higher after threat inflation (with or without rehearsal) at the beginning ($BF_{2c} = 63.08$) and at the end ($BF_{2c} = 27.92$) of the rehearsal phase (see Table S6). The data were more likely under H2 than the other hypotheses at the beginning of the rehearsal phase (all $BF_{s2X} > 277.17$). Yet, at the end of the rehearsal phase, H2 was more likely than H1, H3, and H4 ($BF_{s2X} > 4.57$), but not H5 ($BF_{25} = 1.58$). Together, these findings suggest that threat rehearsal did not affect threat expectancy and distress to CS-. In contrast, threat inflation resulted in higher distress, but not threat expectancy, to CS-, but this effect was uncertain at the end of the rehearsal phase.

4. Discussion

The aim of this preregistered experiment was to examine whether threat rehearsal, threat inflation, or both would increase threat expectancy and distress toward a generalization stimulus (GS). Manipulation checks showed that these manipulations were successful. The hypotheses were tested separately for the two outcome variables: threat expectancy and distress ratings. There were two key findings. First, in the beginning of the rehearsal phase, threat expectancy ratings towards the GS were higher after threat rehearsal, threat inflation, or both, compared to the passive control condition. At the end of the rehearsal phase, only rehearsal (with or without inflation) resulted in higher threat expectancy. Second, for subjective distress, our findings indicated that threat inflation (with or without threat rehearsal) resulted in higher distress ratings toward the GS at the start of the rehearsal phase. At the end of this phase, threat inflation resulted in higher distress ratings, and there was inconclusive evidence whether threat rehearsal amplifies this effect.

To our knowledge, this is the first study showing that mental imagery-based threat rehearsal in the presence of a novel stimulus increases threat expectancy toward this stimulus in healthy individuals. Research has shown that distressing mental imagery is common in individuals with trauma and anxiety-related disorders. It can consist of

autobiographical memories of past events, but can also involve imaginal extensions (elaboration) of such events or hypothetical fear-provoking future events (see Berntsen, 2019; Brewin et al., 2010; Engelhard, van den Hout, Janssen, & van der Beek, 2010; Marks, Franklin, & Zoellner, 2018). For instance in PTSD, mental rehearsal and threat inflation can manifest as repeated intrusive memories of worse moments of the event or worst case scenarios (what could have happened). The current study extends earlier work showing that aversive mental imagery can enhance fear acquisition and impede extinction (Mertens et al., 2020), and that mental rehearsal of threat increases threat expectancy to a safety cue (Krypotos et al., 2020). Although there was no specific effect for rehearsal versus inflation at the beginning of the rehearsal phase, we did find higher threat expectancy ratings for the rehearsal versus no rehearsal groups at the end of the rehearsal phase. Interestingly, threat rehearsal did not materialize on subjective distress at the start of the rehearsal phase, but only at the end if it had been combined with threat inflation. Thus, threat inflation likely augments the effects of repeated threat rehearsal on subjective distress. Taken together, the findings suggest that particularly repeated threat rehearsal may be involved in fear overgeneralization and may hamper extinction learning. Interestingly, a parallel finding was recently reported in a clinical study showing that rehearsal of safety learning strengthens extinction learning (McGlade & Craske, 2021). Yet, they did not use a no rehearsal comparison group, so it is unclear how to interpret their imagery-based rehearsal effects.

This study also found that threat inflation was followed by increased subjective distress toward a generalization stimulus, both at the start and the end of the rehearsal phase. At the end of the rehearsal phase, this effect of threat inflation was even more substantial for participants who rehearsed the inflated US. Thus, threat inflation may play a crucial role in overgeneralization of distress, perhaps especially when people repeatedly imagine an inflated threat, or when threat is inflated mentally (see Hirsch, Clark, & Mathews, 2006). These effects of threat inflation were specific for distress. This suggests that threat inflation may be better quantified with distress rather than threat expectancy outcome measures. Perhaps the use of expectancy measures, which do not necessarily reflect severity of threat, may explain some null findings of previous threat inflation studies (e.g., de Jong, Muris, & Merckelbach, 1996).

The findings have several potential clinically relevant implications. Repeated mental imagery of threat, especially in case of an inflated threat, may be involved in the overgeneralization of fear and etiology of clinical anxiety, but more research is needed to further examine its exact role not only directly after threat acquisition but also later on (after memory consolidation), as will often occur naturalistically. Perhaps, interventions that target mental imagery of threat prevent the development of clinical anxiety in high-risk individuals (e.g., after trauma exposure). Our findings also suggest that threat rehearsal may conceivably hamper exposure learning and, therefore, may need to be addressed in patients seeking treatment for anxiety disorders. For example, imagery of desired behavior or outcomes may help to maximize treatment effects. Indeed, rehearsal of safety information (Carpenter, Moskow, & Hofmann, 2021; McGlade & Craske, 2021) or the addition of imagery-based interventions, such as imagery-rescripting (e.g., Dibbets, Poort, & Arntz, 2012; Morina, Lancee, & Arntz, 2017) or positive mental imagery (Landkroon, van Dis, et al., 2021), boost exposure effects.

Our study brings forth several directions for future research. An interesting new avenue for research could be to examine to which extent effects of threat rehearsal depend on mental imagery. That is, some studies have shown that (abstract) verbal threat rehearsal could facilitate the generalization of fear potentiated startle (Gazendam & Kindt, 2012) and threat expectancy (Van Lier et al., 2014, 2015). On the one hand, abstract verbal threat rehearsal (e.g., worry) may advance overgeneral autobiographical memories which have been associated with heightened fear generalization (Lenaert et al., 2012). On the other hand,

following the findings of Krypotos et al. (2020) and the current study, specific imagery-based threat rehearsal may amplify generalization by directly creating new fear-relevant associations. So future studies could directly compare whether and how different forms of threat rehearsal (e.g., verbal versus imagery-based; specific versus general) differently affect fear generalization. Another direction for future research could be to examine the role of involuntary mental imagery in fear generalization, because anxiety patients typically suffer from intrusive, involuntary mental imagery of threat (Holmes & Mathews, 2010; Pearson & Westbrook, 2015). Future studies could, for example, add measures of involuntary mental imagery (e.g., Hageraars & Arntz, 2012) or a conditioned-intrusion paradigm (e.g., Landkroon, Saleminck, & Engelhard, 2021).

Some limitations of the current study should be noted. First, the test phase could not be used, in which CSs and multiple GSs, were presented, so it is unclear whether our effects are restrained to the rehearsed generalization stimulus, transfer to other GSs, and persist beyond the manipulation phase. Therefore, future studies may include an additional control stimulus that does not share features with the CS+, to elucidate the extent to which our effects depend on generalization or instruction. In addition, it is unclear whether the threat inflation effects can be attributed to actual threat inflation or whether the presentation of the aversive stimulus would have created a threatening context. This should be further examined, because the role of threat inflation in the etiology of clinical anxiety has been questioned (Armfield, 2006). Finally, it is unclear whether our findings may differ across individuals with different ethnic identifications or geographic backgrounds. The strengths of our study are the successful manipulations, the trial-by-trial measurement of threat expectancy and distress, and the advanced statistical analyses, allowing direct comparisons between hypotheses.

Overall, our findings suggest that repeated threat rehearsal increases generalization of threat expectancy. In combination with threat inflation, it also increases generalized distress. Future studies should replicate the findings and examine the potential clinical utility of modulating imagery to prevent clinical anxiety.

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CRediT authorship contribution statement

Eva A.M. van Dis: Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing, Conceptualization, Visualization. **Muriel A. Hageraars:** Conceptualization, Investigation, Methodology, Supervision, Writing – review & editing. **Iris M. Engelhard:** Conceptualization, Funding acquisition, Investigation, Methodology, Supervision, Writing – review & editing.

Declaration of competing interest

We have no conflicts of interest with respect to the authorship or the publication of this article.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jbtep.2024.101917>.

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