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Devaluation of threat memory using a dual-task intervention does not reduce context renewal of fear

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ABSTRACT

Many patients who benefit from exposure-based therapy for anxiety disorders fail to maintain their gains. Learned fear may return when they encounter phobic stimuli in a different context than the one in which extinction occurred. In the current pre-registered experiment, we tested whether threat memory devaluation reduces context renewal of fear. A dual-task intervention was used to devalue threat memory. During this intervention, individuals recall the threat memory while simultaneously performing a demanding secondary task (e.g., making eye movements). On day 1, participants ($N = 75$) underwent fear acquisition with an aversive film clip in context A. On day 2, 25 participants were assigned to each group, namely a dual-task group, or one of two control groups: recall only task (without the dual-task) or no intervention. Afterwards, all participants underwent extinction training in context B and were then exposed to context A again in a test phase. The dual-task intervention effectively degraded threat memory compared to no intervention, but the recall only intervention was also partly effective. However, all three groups showed comparable fear renewal on subjective and physiological measures. This indicates that threat memory devaluation was not effective to prevent context renewal.

1. Introduction

Cognitive Behavioral Therapy (CBT) is the treatment of choice for anxiety disorders (National Institute for Health and Clinical Excellence, 2011). However, many patients who benefit from it fail to maintain their gains (e.g., McNally, 2007). Fear conditioning theory is useful to explain the extinction and return of fear (e.g., Mineka & Zinbarg, 2006; Vervliet, Craske, & Hermans, 2013b). After repeated exposure to feared stimuli without the occurrence of the expected threat, fear is typically extinghuised. According to the inhibitory learning model, extinction training involves learning of new safety associations that inhibit threat associations. However, this inhibition is fragile: under certain conditions, such as a passage of time ('spontaneous recovery') or a change in context ('renewal'), extinguished fear may return (Bouton, 2002; Craske, 2015; Craske, Treanor, Conway, Zbozinek, & Vervliet, 2014). A context change indicates a different context than the one in which fear was extinguished (e.g., non-therapy setting vs. therapy setting).

A potential approach to diminish learned fear more permanently is by devaluing the threat memory itself. That is, learned fear results not only from threat expectancy (which is targeted by exposure in vivo), but also from the intensity of the threat memory ("threat intensity"; Davey, 1997; Vervliet, Craske, et al., 2013b). Threat intensity may relate to idiosyncratic memories of past events and to imagined future threat evens (e.g., see Engelhard, van den Hout, Janssen, & van der Beek, 2010; Holmes & Mathews, 2010). A stimulus that signals a high expectancy of intense threat will elicit strong fear; a low expectancy and/or weak threat will elicit less fear (Vervliet, Craske, et al., 2013b). An important implication of the memory devaluation approach is that even after a context switch, when threat expectancy may be high again, fear responses can remain low when threat intensity is devalued. Laboratory studies have indeed shown that an increase or a decrease of threat intensity can increase or decrease conditioned fear, respectively (Hosoba, Iwanaga, & Seiwa, 2001). Likewise, habituation decreases the perceived intensity of threat and reduces context renewal of conditioned fear (Haesen & Vervliet, 2015; Leer, Haesen, & Vervliet, 2018).

In these studies, the *actual* threat stimulus was used during the devaluation procedure. Regarding potential therapeutic applications, it is more fruitful to manipulate the *mental representation* of threat. Mental images and memories of threat can occur in any sensory modality but are typically visual (e.g., Ehlers et al., 2002; Engelhard, van den Hout, Arntz, & McNally, 2002; Engelhard et al., 2010). Imagery-based treatments to modulate them are imaginal exposure, imagery rescripting, and eye movement desensitization and reprocessing (EMDR), which are effective treatments for trauma-related disorders (Arntz, 2012; Bisson et al., 2007; Powers, Halpern, Ferenschak, Gillihan, & Foa, 2010).

Several studies have examined whether these methods devalue

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threat memories in the laboratory and can be used to reduce the return of fear. Specifically, imagery rescripting aims to alter a threat memory through imagination of a more neutral or positive ending and targets reappraisal (Morina, Lancee, & Arntz, 2017). Research has indicated that adding imagery rescripting to extinction training, compared to extinction training alone, attenuates renewal of threat expectancy (Dibbets, Poort, & Arntz, 2012). Likewise, EMDR may deflate threat memory by recalling the threat memory while performing a demanding dual-task (e.g., making bilateral eye movements) simultaneously (Engelhard, McNally, & van Schie, 2019). Several fear conditioning studies found that this dual-task approach decreases conditioned fear responses. First, a dual-task intervention, compared to merely recalling the memory (which serves to control for the imaginal exposure component; Powers et al., 2010), reduced conditioned subjective fear but not psychophysiological responses (Leer, Engelhard, Altink, & van den Hout, 2013a). Second, a dual-task intervention reduced renewal of threat expectancy, compared to a filler task (no intervention) or mere recall of threat memory, but there was no evidence for threat devaluation (Leer, Engelhard, Dibbets, & van den Hout, 2013b). Finally, dual-tasking or imagery rescripting interventions did not devalue threat memory and did not reduce threat expectancy, compared to extinction training (Dibbets, Lemmens, & Voncken, 2018).

In summary, laboratory studies have examined whether mental imagery-based procedures focusing on threat devaluation reduce fear, but the evidence is mixed, and it is unclear whether these interventions can prevent the return of fear. The current study examined whether a dual-task intervention before extinction training reduces fear renewal. This study differs from the above-mentioned experiments in several ways. First, they used a disgusting film clip (Leer, Engelhard, Altink, et al., 2013a) or aversive picture (Leer, Engelhard, Dibbets, et al., 2013b) as threatening stimulus. Aversive pictures do not entail the complexity of real-world experiences (Scheveneels, Boddez, Vervliet, & Hermans, 2016). Therefore, the current study used a fear-relevant audiovisual aversive stimulus showing a traumatic scene (see Dibbets et al., 2018; Landkroon, Mertens, Sevenster, Dibbets, & Engelhard, 2019). Second, previous studies presented acquisition and intervention phases on the same day, so the intervention may have interfered with the consolidation process instead of with the threat memory (McGaugh, 2000). To prevent this possibility, we used a two-day paradigm and presented the acquisition and intervention phases on separate days. Third, previous research used a visual filler task as 'no intervention' control group, which also reduced intensity of threat memory (Leer, Engelhard, Dibbets, et al., 2013b). A filler task might work as dual-task, which is why the current study used a 'no task' control group instead. Finally, in earlier studies, the threat devaluation intervention followed the extinction phase. However, in clinical practice, drop-out in CBT is a major problem (Fernandez, Salem, Swift, & Ramtahal, 2015). Devaluing threat memory before exposure might increase the willingness of patients to start exposure therapy. Therefore, in the current study, the intervention preceded the extinction phase.

A two-day fear conditioning paradigm (Landkroon et al., 2019) was used in which context was manipulated to elicit fear renewal. On day 1, fear acquisition took place in context A. On day 2, participants were randomly allocated to one of three groups (dual-task, recall only task, or no task), before extinction took place in context B. Afterwards, renewal was tested in context A. We hypothesized that the dual-task and recall only task groups, relative to the 'no task' group, would show reduced unpleasantness and vividness of threat memory and that the dual-task group would show stronger reductions than the recall only group. Moreover, we hypothesized that the dual-task and recall only task groups, relative to the 'no task' group, would show reduced fear on the first extinction trial and after a context switch on conditioned responses. Research has shown that prolonged recall of an aversive memory can lead to a reduction of vividness and emotionality in the lab (van Veen, van Schie, van de Schoot, van den Hout, & Engelhard, 2019), which is consistent with the efficacy of imaginal exposure treatment for posttraumatic stress disorder (Powers et al., 2010). Therefore, we also considered the possibility of reduced fear on the first extinction trial and reduced renewal in the recall only group.

2. Method

2.1. Pre-registration

The hypotheses, sample size, methods, and data-analysis steps of this study were pre-registered on the Open Science Framework prior to finishing data collection (https://osf.io/aCS-k/).

2.2. Participants

We recruited 84 participants at the campus of Utrecht University. Exclusion criteria were: self-reported (past or current) mental health problems or a serious medical condition, color blindness, hearing/eye sight difficulties, pregnancy, and medication that influences attention, memory, and concentration. Nine participants were excluded prior to data analyses for the following reasons. One was excluded due to equipment failure. Two were excluded, because they showed no differential learning on threat expectancy (i.e., higher unconditioned stimulus [US] expectancy ratings for conditioned stimulus [CS] + than CS- at the end of the acquisition phase; see our pre-registration). Four participants quit the experiment on day 1 because they found the US too aversive. Two participants did not complete the second day of testing, because they found the US too aversive or felt ill. The final sample consisted of 75 participants (17 male/58 female; M_{age} = 20.96, SD_{age} = 2.53). Sixty-nine were students (60 undergraduate, 9 graduate). Participation was compensated with course credit or money. All participants gave written informed consent. The Ethics Committee of the Faculty of Social Sciences of Utrecht University approved this study (FETC16-054).

2.3. Stimuli

A validated paradigm to induce renewal with an audiovisual US was used (Landkroon et al., 2019), which was based on work by Milad, Orr, Pitman, and Rauch (2005) and Dibbets et al. (2018). Pictures of two different rooms were used as context, in which the same lamp was present. CSs were light colors of the lamp (blue and yellow). The US was an aversive film clip (6 s), that depicts a woman falling down in a kitchen, spilling boiling water on her face, and screaming (volume peak: 95 dB). At the end of the clip, a close-up of her burned face is shown. This clip was used in a promotional ad from the health and safety marketing campaign from Ontario's workers' compensation board and did not contain real-life footage. Previous research demonstrated that participants do not habituate to this US (Dibbets et al., 2018). The experiment was programmed in E-Prime 2.0 (Psychology Software Tools).

2.4. Questionnaires

State and trait anxiety were assessed with the State-Trait Anxiety Inventory (STAI-DY; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983), to test whether state and trait levels of anxiety did not differ between groups before the experiment, because these variables are associated with fear learning (e.g., Duits et al., 2015; Lonsdorf & Merz, 2017; but see Engelhard, de Jong, van den Hout, & van Overveld, 2009; Torrents-Rodas et al., 2013).

2.5. Outcome measures

2.5.1. US memory ratings

Two questions measured unpleasantness ('How unpleasant is the image you recalled?') and vividness ('How vivid is the image you

recalled?') of US memory on a visual analogue scale (VAS) ranging from 0 (= not at all unpleasant/vivid) to 100 (= very unpleasant/vivid) (Leer, Engelhard, Altink, et al., 2013a).

2.5.2. Conditioned responses

Subjective measures. Participants rated US expectancy during each CS presentation on a VAS presented at the bottom of the computer screen ('Do you expect the aversive film clip to follow?') ranging from −5 (= definitely not), 0 (= uncertain) to 5 (= definitely). Before each phase of the experiment and after every three trials, fear, valence, and arousal in response to the CSs were measured with pen-and-paper. Fear was measured on a 9-point scale ('How fearful do you feel when you see this picture?') ranging from 1 (= not at all) to 9 (= very much). Valence and arousal were measured with Self-Assessment Manikins (SAM; Bradley & Lang, 1994), ranging from 1 (= negative/no activation) to 9 (= positive/a lot of activation). For the ratings, CSs were presented in a fixed order (first yellow, then blue).

Psychophysiological measures. A BioSemi ActiveTwo system was used to register electromyography (EMG) and skin conductance responses (SCR). Two reference electrodes were positioned on the forehead (approximately 1 cm below the hairline). To measure fear potentiated startle (FPS), two 4 mm Ag/AgCl electrodes filled with electrolyte conductive gel (Signa) were attached to the left orbicularis oculi muscle (approximately 1 cm below the pupil and 1 cm below the lateral canthus). SCR was measured with two 5 mm Ag/AgCl electrodes filled with electrolyte conductive gel (Signa), which were attached to the proximal part of the palm of the left hand. Recording and analyses of FPS and SCR was similar to previous work (Landkroon et al., 2019) and according to guidelines (Blumenthal et al., 2005; Boucsein et al., 2012; Pineles, Orr, & Orr, 2009).

2.6. Procedure

2.6.1. Day 1

Electrodes for psychophysiological measures were attached and headphones were placed. Then, participants completed the STAI-S and STAI-T on the computer, and they received information about the woman in the aversive film clip. They read that the woman was a sous-chef in a restaurant who would get promoted next year and get married the following weekend (see Dibbets et al., 2018; Landkroon et al., 2019). Participants then viewed a 10-s version of the aversive film clip. Afterwards, they received instructions about the contingencies between the CSs and US (Landkroon et al., 2019; Milad et al., 2005). Participants were instructed that a lamp would be presented on screen that could turn either blue or yellow when it was lit, and that one of these colors would be followed by the aversive film clip. The other color would never be followed by the film clip on either day. They were instructed to learn to predict when the aversive film clip would be shown. They practiced rating the US expectancy scale and rated scales measuring fear, valence, and arousal to the CSs. Before the acquisition phase, they heard 10 habituation startle probes, which were presented to stabilize startle reactivity (Blumenthal et al., 2005).

Acquisition phase. The acquisition phase consisted of two blocks. Per block, participants were exposed to each CS three times in a random order, with no more than two consecutive repetitions. Context A (i.e., picture of desk or bookcase) was presented throughout the acquisition phase, see Fig. 1. Context presentation and CS type were counterbalanced across participants. After 6 s, the CS was presented for 8 s (desk or bookcase with lit lamp). Within 7 s after CS onset, participants could rate their US expectancy. Then the startle probe was administered through headphones (50 ms; 104 dB). At CS+ offset, the US was presented, followed by the intertrial interval (ITI), while at CS- offset the ITI started immediately. The ITI was 10, 12, or 14 s and consisted of the context picture. In half of the trials, a startle probe was presented at the end of the ITI and then the ITI duration was doubled, which increased total ITI duration to 20, 24, or 28 s, respectively. After the acquisition phase, participants were asked to select the most aversive image of their memory of the film clip and to recall this image and focus on it for 10 s. Afterwards, they rated the unpleasantness and vividness of the US memory.

2.6.2. Day 2

Intervention phase. Twenty-four hours later, participants were seated in the same laboratory. The 'no task' control group started with the extinction phase. The other two groups were asked to retrieve the most aversive image from their US memory and then rated its unpleasantness and vividness. Then, the intervention started. Participants in the dual-task and recall only groups were instructed to recall the image and keep it in mind for 24 s. Only the dual-task group made simultaneous eye movements by visually tracking a dot on the computer screen moving from left to right and back (1.2 Hz, see van Veen et al., 2015), without moving their head. After 24 s, there was a 10 s break. There were 4 trials per block, and 4 blocks. After each block, participants were asked to recall the image again and to rate its unpleasantness and vividness. Total duration of each intervention was about 10 min (including the 10-s breaks).

Extinction phase. Electrodes were then attached and participants were instructed to remember what they had learned on the previous day (see Milad et al., 2005). They rated fear, valence, and arousal to the CSs and heard 10 startle probes. The extinction phase existed of four blocks and the US was never presented. The first CS presentation was counterbalanced across participants. The extinction phase was presented in a different context (B) than the acquisition phase. Timing and CS measures (fear, valence, arousal) were similar to day 1. At the end of the extinction phase, all three groups were asked to recall the aversive image and rate its unpleasantness and vividness.

Renewal phase. The context then switched to the original acquisition context A. The renewal phase consisted of two blocks, again without US presentation. Timing, CS measures, and the US memory ratings were identical to previous phases. The presentation of the first CS was counterbalanced across participants.

Reinstatement phase. Within context A, the sound of the original US was presented three times in a row. Next, one block of CSs was presented. Timing, CS measures, and US memory ratings were identical to previous phases. The CS+ was shown first. This reinstatement procedure was included for exploratory purposes only and results are not presented here.

End of experiment. Participants in the dual-task group were asked whether they were able to track the dot with their eyes on a VAS (0 = not at all, 100 = absolutely). Additionally, participants in both the dual-task and recall only groups were asked whether they could adhere to the instructions to vividly recall the US memory (0 = not at all vivid, 100 = extremely vivid). All participants were asked to which degree they thought their memory of the film clip had changed (0 = not at all, 100 = extremely). Finally, electrodes were removed, and participants were debriefed and reimbursed.

2.7. Data analyses

2.7.1. Data preparation

Startle responses were scored by subtracting the average activity during the baseline period (30 ms before to 20 ms after startle probe onset) from the peak amplitude in the 20–150 ms interval after probe onset. Individual variation of startle responses was reduced with a T-transformation (Blumenthal et al., 2005). SCR were scored by subtracting the average of the baseline period (2 s before CS onset) from the maximal amplitude during the 1–7 s interval after CS onset (Pineles et al., 2009). Similar to the study by Landkroon et al. (2019), individual variation in SCR was reduced by a range correction and then normalized with a log-transformation (Bouscein et al., 2012). A minimal response value of 0.02 μS was applied (Cacioppo, Tassinary, & Berntson, 2007). When the assumption of sphericity was violated, degrees of

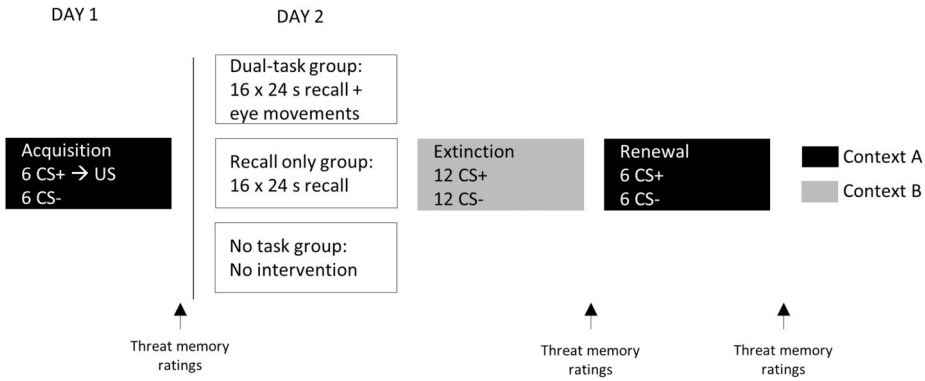

Fig. 1. Acquisition and renewal phases were presented in context A. The extinction phase was presented in context B. During the dual-task and recall only interventions, the background color of the screen was black. After three trials, CSs were rated (fear, valence, and arousal).

freedom were corrected with Greenhouse-Geisser ($\varepsilon < .75$) or Huyn-Feldt ($\varepsilon > .75$).

2.7.2. Randomization check

We tested whether groups differed on state anxiety (STAI-S), trait anxiety (STAI-T), and US memory ratings after the acquisition phase, using one-way ANOVAs. We also explored whether the dual-task and recall only groups differed in retrieving the US memory vividly during the intervention, and whether the three groups differed in whether they thought their US memory had changed, using one-way ANOVAs.

2.7.3. Unpleasantness and vividness of US memory

First, we tested whether the dual-task group showed larger reductions in unpleasantness and vividness of threat memory than the recall only group during the intervention, with two repeated measures ANOVAs. Then, we tested whether the dual-task had lower unpleasantness and vividness ratings of threat memory than the other two groups after the extinction and renewal phases, using 2 (Time: pre vs. post) x 3 (Group: dual-task, recall only, no task) repeated measures ANOVAs.

2.7.4. Acquisition and extinction phase

To examine whether differential acquisition and extinction took place, we analyzed acquisition and extinction phases with separate 2 (Stimulus: CS+ vs. CS-) x 6 or 12 (Trial) repeated measures ANOVAs (with Group as between-subjects factor) on US expectancy, FPS, SCR, and subjective fear, valence, and arousal to the CSs. Also, to assess whether the dual-task group showed reduced conditioned fear on the first trial of extinction, compared to the recall only and no task groups, we performed a 2 (Stimulus: CS+ vs. CS-) x 2 (Trial: last acquisition vs. first extinction trial) x 3 (Group: dual-task, recall only, no task) repeated measures ANOVA.

2.7.5. Renewal

To examine whether the dual-task group showed less renewal of conditioned fear, compared to the other two groups, we conducted a 2 (Stimulus: CS+ vs. CS-) x 2 (Trial: last extinction trial vs. first renewal trial) x 3 (Group: dual-task, recall only, no task) repeated measures ANOVA (following Vervliet, Baeyens, van den Bergh, & Hermans, 2013a).

3. Results

There were no group differences in gender distribution, $\chi^2(2) = 1.07$, $p = .59$, and in age, state, trait anxiety, and whether participants thought their US memory had changed during the experiment, $Fs < 1$, see Table 1. At the end of the experiment, the recall only group indicated that they retrieved the US memory more vividly during the intervention than the dual-task group, $t(48) = 2.63$, $p = .01$, $d_s = 0.74$.

Table 1
Distribution of gender (male/female frequency), means (SD) of age, state anxiety (STAI-S), trait anxiety (STAI-T), adherence to instructions during intervention phase (i.e., making eye movements and vividly recalling the US), and whether participants thought their US memory changed for the three groups ($n = 25$ per group).

	Dual-task	Recall only	No task
Gender	4/21	6/19	7/18
Age	20.56 (2.24)	21.08 (3.17)	21.24 (2.11)
STAI-S	34.00 (8.34)	33.60 (8.77)	35.28 (8.07)
STAI-T	35.32 (8.81)	36.52 (7.41)	37.32 (7.20)
Eye movements	74.40 (19.55)	–	–
Recall US	59.44 (20.26)	73.20 (16.63)	–
Memory changed	45.96 (22.08)	41.64 (26.97)	37.12 (20.61)

3.1. US memory unpleasantness and vividness

3.1.1. Post-acquisition and intervention

Directly after the acquisition phase, there were no significant differences between the three groups in ratings of US unpleasantness, $F(2, 72) = 1.11$, $p = .36$, and vividness, $F(2, 72) = 0.79$, $p = .46$, see Figs. 2 and 3. Both intervention groups showed reduced unpleasantness during the intervention phase, $F(2.07, 99.30) = 13.35$, $p < .01$, $\eta_p^2 = .22$, which did not significantly differ between groups, $F(2.07, 99.30) = 2.23$, $p = .11$, $\eta_p^2 = .04$ (trial x group). Likewise, both groups showed reduced vividness during the intervention phase, $F(1.84, 88.28) = 5.46$, $p < .01$, $\eta_p^2 = .10$, which did not significantly differ between groups, $F(1.84, 88.28) = 0.54$, $p = .57$, $\eta_p^2 = .01$ (trial x group).

3.1.2. Post-extinction and post-renewal

Unpleasantness decreased from after the acquisition phase to after the extinction phase, $F(1, 72) = 67.12$, $p < .01$, $\eta_p^2 = .48$, and this differed between groups, $F(2, 72) = 3.12$, $p = .05$, $\eta_p^2 = .08$. All three groups showed a reduction (dual-task: $t(24) = 6.17$, $p < .01$, $d_z = 1.23$, recall only, $t(24) = 5.76$, $p < .01$, $d_z = 1.15$, no task: $t(24) = 2.62$, $p = .02$, $d_z = 0.52$). Furthermore, independent samples t-tests showed that as predicted, unpleasantness decreased more in the dual-task group than in the no task group, $t(48) = 2.33$, $p = .02$, $d_s = 0.66$. From directly after acquisition to after renewal, unpleasantness also decreased, $F(1, 72) = 94.07$, $p < .01$, $\eta_p^2 = .57$, and this decrease differed again between groups, $F(2, 72) = 3.19$, $p = .047$, $\eta_p^2 = .08$. All three groups showed again a reduction (dual-task: $t(24) = 7.63$, $p < .01$, $d_z = 1.53$, recall only: $t(24) = 6.16$, $p < .01$, $d_z = 1.23$, no task: $t(24) = 3.38$, $p < .01$, $d_z = 0.68$), and again as predicted, compared to the no task group, the decrease in unpleasantness was larger for the dual-task

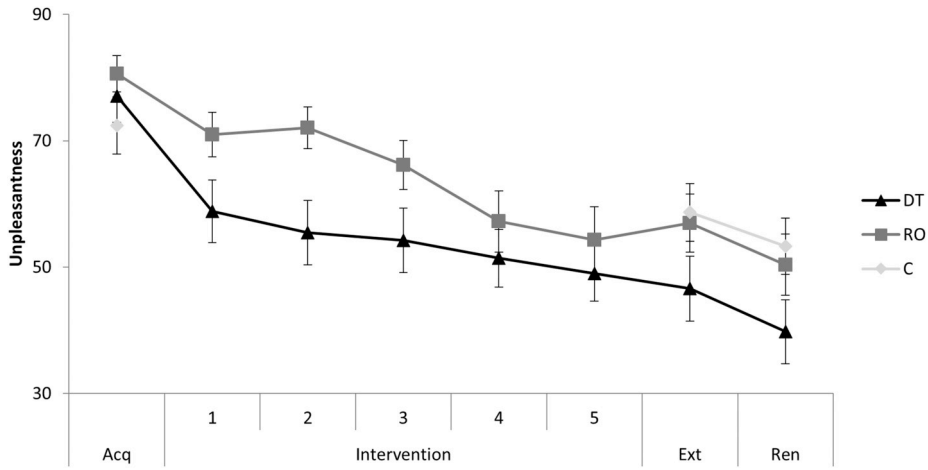

Fig. 2. Unpleasantness of the threat memory after acquisition (Acq), during the intervention, after extinction (Ext), and after renewal (Ren) in the dual-task (DT), the recall only (RO), and the no task control (C) groups. Error bars represent standard error of the mean (SEM).

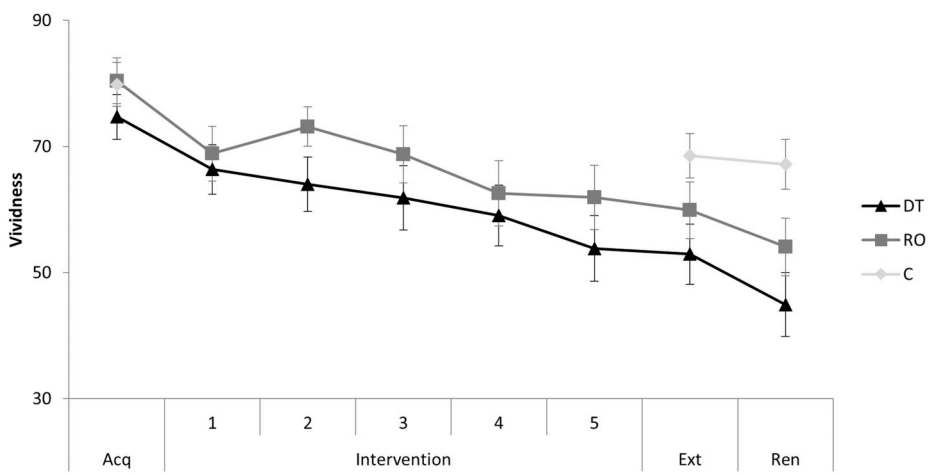

Fig. 3. Vividness of the threat memory after acquisition (Acq), during the intervention, after extinction (Ext), and after renewal (Ren) in the dual-task (DT), recall only (RO), and no task control (C) groups. Error bars represent SEM.

group, $t(48) = 2.45$, $p = .02$, $d_s = 0.69$.

Vividness decreased from after acquisition to after extinction in all groups, $F(1, 72) = 56.81$, $p < .01$, $\eta_p^2 = .44$, but contrary to our predictions, this did not differ between the three groups, $F(2, 72) = 1.93$, $p = .15$, $\eta_p^2 = .05$. From after the acquisition phase to after the renewal phase, vividness also decreased, $F(1, 72) = 74.98$, $p < .01$, $\eta_p^2 = .51$, and this decrease did differ between groups, $F(2, 72) = 3.88$, $p = .03$, $\eta_p^2 = .10$. All three groups showed a reduction (dual-task: $t(24) = 5.45$, $p < .01$, $d_z = 1.09$, recall only: $t(24) = 6.24$, $p < .01$, $d_z = 1.25$, no task: $t(24) = 3.23$, $p < .01$, $d_z = 0.65$). As predicted, compared to the no task group, the decrease in vividness was larger for the dual-task group, $t(48) = 2.54$, $p = .01$, $d_s = 0.72$, and the recall only group, $t(48) = 2.37$, $p = .02$, $d_s = 0.67$. However, the dual-task and recall only groups did not differ in reduction of vividness, $t(48) = 0.50$, $p = .62$, $d_s = 0.14$.

3.2. Subjective measures

3.2.1. US expectancy

Acquisition and extinction. Differential responding on US expectancy increased between the CS+ and CS- over the 6 trials of acquisition, $F(2.66, 170.44) = 241.00$, $p < .01$, $\eta_p^2 = .79$ (stimulus x trial), for all three groups, $F(5.29, 163.96) = 0.66$, $p = .67$, $\eta_p^2 = .02$ (stimulus x trial x group) (see Fig. 4).[1] During the extinction phase, differential responding reduced, $F(3.36, 198.45) = 55.69$, $p < .01$, $\eta_p^2 = .49$ (stimulus x trial), for all groups, $F(6.72, 191.56) = 1.39$, $p = .21$, $\eta_p^2 = .05$ (stimulus x trial x group). The change from the last acquisition trial to the first extinction trial also did not differ between the three groups, $F(2, 69) = 1.79$, $p = .18$, $\eta_p^2 = .05$ (stimulus x trial x group). This suggests that the dual-task and recall only interventions had no effect on US expectancy directly after the intervention.

Renewal. There was differential renewal in all groups, with a larger increase to CS+ than to CS-, $F(1, 70) = 130.48$, $p < .01$, $\eta_p^2 = .65$ (stimulus x trial). We did not observe differences in renewal between the groups, $F(2, 70) = 1.06$, $p = .35$, $\eta_p^2 = .03$ (stimulus x trial x group). Thus, a context switch increased differential US expectancy similarly in all three groups. US expectancy re-extinguished as evidenced by reduced differential conditioning in all groups, $F(2.62, 172.96) = 60.12$, $p < .01$, $\eta_p^2 = .48$ (stimulus x trial).

[1] When participants did not use a mouse click to give their US expectancy, we classified these values as missing (51 MVs; 1.26%). In the analyses, missing cases were deleted listwise. We also conducted the analyses without excluding these data points, which yields identical significance and direction of the results reported here.

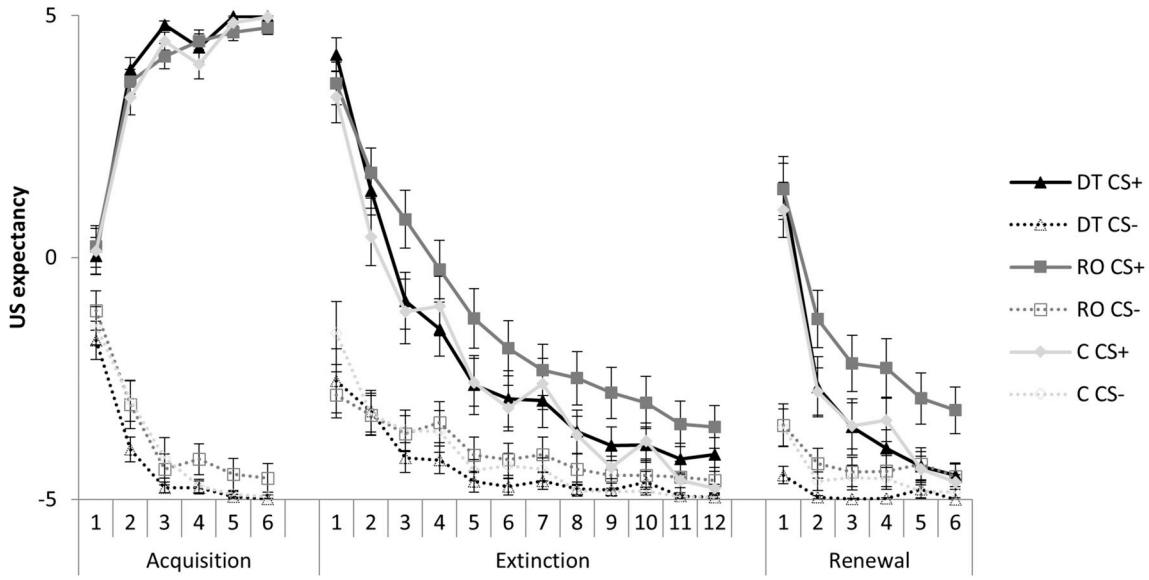

Fig. 4. US expectancy during acquisition, extinction, and renewal in the dual-task (DT), recall only (RO), and no task control (C) groups. Error bars represent SEM.

3.2.2. CS ratings

The results of fear, valence, and arousal to the CSs resemble the results of US expectancy. For parsimony, the data and the test statistics of the CS ratings are not described here but are provided in the supplementary results.

3.3. Psychophysiological measures

3.3.1. Fear potentiated startle

Acquisition and extinction. Acquisition was evidenced by a main effect of stimulus, $F(2, 148) = 94.65$, $p < .01$, $\eta_p^2 = .56$, but not by a differential increase over time, $F(9.26, 685.22) = 0.72$, $p = .69$, $\eta_p^2 = .01$ (stimulus x trial) (see Fig. 5). The mean startle response amplitude for CS+ ($M = 55.79$, $SD = 5.36$) was higher than for CS- ($M = 50.32$, $SD = 4.11$), $t(74) = 9.88$, $p < .01$, $d_z = 1.14$, and ITI ($M = 47.46$, $SD = 4.62$), $t(74) = 12.49$, $p < .01$, $d_z = 1.44$. The mean startle response amplitude was also higher for CS- than for ITI, $t(74) = 4.61$, $p < .01$, $d_z = 0.53$. This indicates successful acquisition (i.e., larger startle responses for CS+ than CS-). There were no group differences, $F(19.23, 692.30) = 0.90$, $p = .59$, $\eta_p^2 = .02$ (stimulus x trial x group) and $F(4, 144) = 1.46$, $p = .22$, $\eta_p^2 = .04$ (stimulus x group). During the extinction phase, FPS diminished to all CSs, $F(7.62, 563.61) = 34.46$, $p < .01$, $\eta_p^2 = .32$ (main effect trial), but did not extinguish differentially, $F(15.26, 1128.94) = 1.50$, $p = .10$, $\eta_p^2 = .02$ (stimulus x trial). A main effect of stimulus indicated that differential responding existed on FPS, $F(2, 148) = 26.97$, $p < .01$, $\eta_p^2 = .27$. The mean startle response amplitude for CS+ ($M = 49.03$, $SD = 2.74$) was higher than for CS- ($M = 47.38$, $SD = 2.56$), $t(74) = 4.22$, $p < .01$, $d_z = 0.49$, and for ITI ($M = 46.25$, $SD = 2.32$), $t(74) = 7.27$, $p < .01$, $d_z = 0.84$. The mean startle response amplitude was also higher for CS- than for ITI, $t(74) = 3.07$, $p < .01$, $d_z = 0.35$. Groups did not differ in extinction, $F(30.29, 1090.60) = 0.75$, $p = .83$, $\eta_p^2 = .02$ (stimulus x trial x group) and $F(4, 144) = 1.09$, $p = .37$, $\eta_p^2 = .03$ (stimulus x group), or the transition from acquisition to extinction phase, $F(4, 144) = 0.55$, $p = .70$, $\eta_p^2 = .02$ (stimulus x trial x group). This suggests that the dual-task and recall only interventions had no effect on FPS directly after the intervention.

Renewal. There was evidence for a non-differential renewal effect, $F(1, 72) = 114.66$, $p < .01$, $\eta_p^2 = .61$ (main effect trial), which did not differ between the three groups, $F(4, 144) = 0.27$, $p = .90$, $\eta_p^2 = .01$ (stimulus x trial x group). FPS re-extinguished, as evidenced by reduced responding in all groups, $F(4.84, 348.49) = 53.55$, $p < .01$, $\eta_p^2 = .43$ (main effect trial).

3.3.2. Skin conductance response

Acquisition and extinction. Acquisition on SCR was evidenced by a significant increase in differential responding between the CS+ and CS-, $F(4.80, 355.07) = 4.84$, $p < .01$, $\eta_p^2 = .06$ (stimulus x trial) (see Fig. 6), and did not differ between groups, $F(10, 360) = 1.47$, $p = .15$, $\eta_p^2 = .04$ (stimulus x trial x group). During the extinction phase, SCR diminished to both CSs, $F(9.95, 736.17) = 8.32$, $p < .01$, $\eta_p^2 = .10$ (main effect trial), but did not extinguish differentially, $F(10.02, 741.45) = 1.25$, $p = .26$, $\eta_p^2 = .02$ (stimulus x trial). SCR was overall higher for the CS+ ($M = 0.054$, $SD = 0.04$) than for the CS- ($M = 0.047$, $SD = 0.03$), $F(1, 74) = 4.92$, $p = .03$, $\eta_p^2 = .06$ (main effect stimulus). There was no difference in extinction between the groups, $F(20.76, 747.23) = 1.00$, $p = .46$, $\eta_p^2 = .03$ (stimulus x trial x group) or the transition from acquisition to extinction phases, $F(2, 72) = 0.86$, $p = .43$, $\eta_p^2 = .02$ (stimulus x trial x group). This suggests that the dual-task and recall only interventions had no immediate effect on SCR.

Renewal. There was evidence for a differential renewal effect on SCR: the increase to CS+ was larger than to CS-, $F(1, 72) = 4.41$, $p = .04$, $\eta_p^2 = .06$ (stimulus x trial), but this did not differ between the three groups, $F(2, 72) = 0.10$, $p = .91$, $\eta_p^2 = .00$ (stimulus x trial x group). SCR re-extinguished in all groups, $F(5, 360) = 2.96$, $p = .01$, $\eta_p^2 = .04$ (main effect trial), with a stronger decrease for CS+ than CS-, $F(4.96, 356.96) = 2.30$, $p = .045$, $\eta_p^2 = .03$ (stimulus x trial). This differential decrease was due to differential renewal and thus CS- responding remained low in the test phase.

4. Discussion

In the current study, we examined whether a dual-task intervention, compared to two control conditions (recall only and no intervention), would reduce the intensity of threat memory and attenuate return of fear. The main findings can be summarized as follows. First, in all three groups, the unpleasantness and vividness of the threat memory decreased during and after the intervention. As predicted, relative to no intervention, the dual-task intervention resulted in a larger decrease in

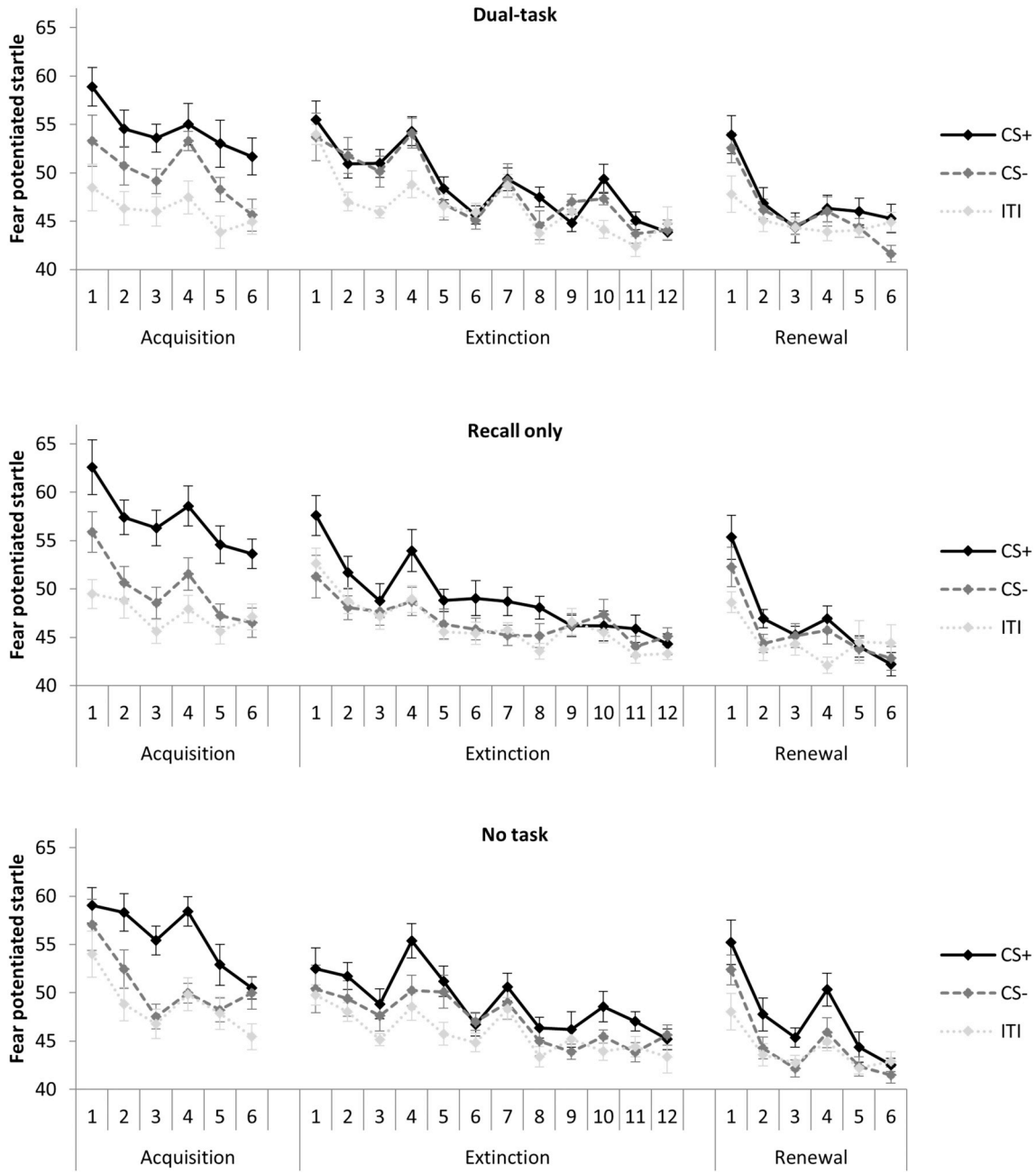

Fig. 5. Fear potentiated startle response during acquisition, extinction, and renewal in the dual-task, recall only, and no task control groups. Error bars represent SEM.

unpleasantness and vividness and the recall only intervention resulted only in a larger decrease in vividness. However, the two intervention groups did not differ in the reduction of unpleasantness and vividness of threat memory during and after the intervention. Second, the three groups did not differ on any of the outcome measures at the first extinction trial, which indicates that the dual-task intervention had no effect on fear responses directly after the intervention. Finally, the three groups demonstrated no difference in renewal on all outcome measures, suggesting that the dual-task intervention did not counter fear renewal.

Both interventions, compared to no intervention, resulted in threat devaluation in terms of memory vividness but only the dual-task intervention reduced memory unpleasantness more than the no task group. In line with our hypothesis, this suggests that the dual-task intervention was more effective than the recall only intervention. Partial effects of the recall only condition may be explained by intervention duration. Earlier studies that demonstrated a superior effect of a dual-task intervention, compared to a recall only intervention, on threat devaluation typically used a short intervention (4 or 6 blocks of 24 s; e.g., Engelhard et al., 2010; Gunter & Bodner, 2008; Leer, Engelhard, Altink, et al., 2013a; van den Hout, Muris, Salemink, & Kindt, 2001). Habituation after such brief exposure may not be expected (see Engelhard et al., 2010). The current study used 16 blocks of 24 s, and recent evidence suggests that when the intervention length of dual-task and recall only interventions is increased to this duration, both interventions affect unpleasantness and vividness of aversive memory (van Veen et al., 2019).

Even though threat memory was devalued, we found no immediate effect on conditioned responses or on fear renewal. Two experiments have found that a dual-task intervention reduces conditioned fear (Leer, Engelhard, Altink, et al., 2013a) or fear renewal (Leer, Engelhard,

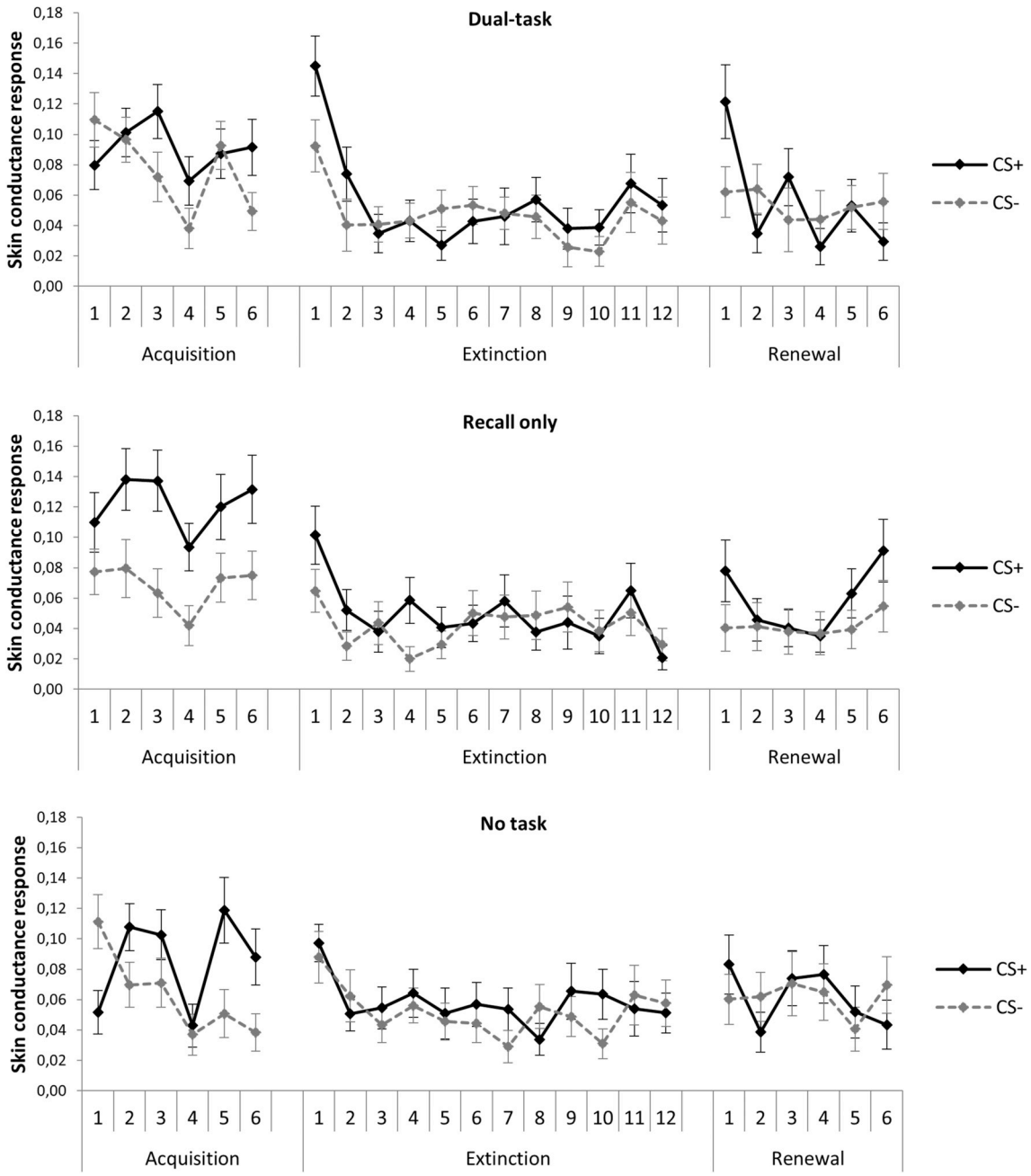

Fig. 6. Skin conductance response (SCR) during acquisition, extinction, and renewal in the dual-task, recall only, and no task control groups. Error bars represent SEM.

Dibbets, et al., 2013b), but they used a one-day paradigm. In the current study, the intervention took place one day after acquisition. Although we used a distressing audiovisual clip to increase the aversiveness and complexity of the US, the unpleasantness of the associated threat memory was already reduced in all three conditions one day later. Therefore, there was less room for the intervention to further devalue threat memory. Moreover, in the current study, the intervention was given before (instead of after; Leer, Engelhard, Dibbets, et al., 2013b) the extinction phase. The extinction phase may have overwritten the effects of the dual-task intervention, which may explain why we did not find group differences on renewal. However, this cannot account for a lack of group differences on the first extinction trial directly after the intervention.

A different interpretation for the finding that the dual-task group showed threat devaluation but not reduced fear renewal is that the intervention effects are context-dependent (during the intervention, a black screen was shown; during the renewal phase, the bookcase or desk were shown). However, this is an unlikely explanation, because studies have shown that the effects of threat memory deflation generalize over contexts (Leer & Engelhard, 2015), and effects of the dual-task intervention persist after a background switch (Leer, Engelhard, Dibbets, et al., 2013b) and over time (Gunter & Bodner, 2008; Leer, Engelhard, & van den Hout, 2014). A more likely explanation is that the intervention was not strong enough to reduce learned fear. Unpleasantness and vividness of threat memory were still high at the end of the intervention (mean score > 45 on a 0–100 scale), indicating that the memory was still relatively aversive. This is in line with previous work on aversive autobiographical memories, where vividness and emotionality ratings remained similarly high after the intervention (e.g., Mertens et al., 2019; van Schie, van Veen, Engelhard, Klugkist, &

van den Hout, 2016). How could the intervention be optimized? One way is to further increase taxation of the dual-task (e.g., by using complex counting rather than making eye movements; van den Hout et al., 2010). Alternatively, in the EMDR protocol, patients are allowed to associate based on the first aversive threat memory and thus deviate from the original image (de Jongh & ten Broeke, 2012), while in the current study only one image was devalued. Also, the intervention could improve when other aspects of the EMDR protocol, rather than merely the dual-tasking component, are used, such as formulating negative cognitions and focusing on improving the validity of positive cognitions (Shapiro, 2017). Moreover, pharmacological interventions (e.g., Kindt, Soeter, & Vervliet, 2009) or other mental imagery-based interventions like imagery rescripting might be more powerful, although a first comparison showed no difference between imagery rescripting and a dual-task procedure on the aversiveness of threat memory and on conditioned responses (Dibbets et al., 2018). Future research may elucidate whether a stronger intervention to devalue threat memory reduces fear renewal. It also seems important to examine whether EMDR or other interventions aimed at devaluing threat memory before exposure therapy for anxiety disorders may facilitate exposure, because a substantial number of patients do not start or drop-out during exposure therapy (Fernandez et al., 2015).

There are several limitations of this study. First, we tested individuals that reported no (history of) psychological problems. It is unclear whether the findings generalize to individuals who suffer from psychological difficulties. In future research, a threat devaluation procedure should be tested in a subclinical sample. Second, as mentioned, the emotional intensity of the threat memory did not decrease to (nearly) 0, thus the intervention may not have been strong enough to result in effects on learned fear. Despite these limitations, several strengths should be noted. First, this study was pre-registered (Asendorpf et al., 2013). Second, a two-day fear conditioning paradigm was used with an audiovisual US to ensure that the intervention intervened with a consolidated, ecologically valid threat memory. Third, the study was well-controlled, using active and passive groups to control for time, general intervention effect, and mere recall of the threat memory. Finally, subjective and physiological outcome measures were collected, which showed the same patterns and enhances confidence in our conclusions.

To summarize, using a two-day paradigm, this study examined whether threat memory devaluation prevents renewal of conditioned fear. Even though threat memory devaluation took place, it did not attenuate the return of fear. Future studies may use a more potent dual-task intervention, use a different intervention (such as imagery rescripting), focus on employing a more realistic threat memory, and examine a subclinical sample. Given the pressing problem of return of fear in clinical practice, there is a need for more research about ways to enhance treatment effects.

Conflicts of interest

The authors declare no conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.brat.2019.103480.

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