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Plasticity of fear memory: a search for relapse prevention

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Context-cue discrimination training during extinction weakens renewal of shock expectancy

Effting, M., Vervliet, B., & Kindt, M. (*under review*). Context-cue discrimination training during extinction weakens renewal of shock expectancy.

Abstract

Background and Objectives. Enhancing the generality of extinction learning is a well-studied strategy to reduce renewal, but may not be very efficient. A more potent strategy might be to weaken the generality of fear learning. Here, we tested whether context-cue discrimination training selectively increases the relevance of one context cue for fear learning and consequently reduces renewal.

Methods. Fear acquisition (CS-US) occurred in Context AX. Next, Condition EXT-only was exposed to simple extinction training (CS-noUS) in Context B. In contrast, Condition EXT-R received repeated alternation between extinction (CS-noUS) in Context B and reacquisition (CS-US) in the joint presence of extinction Context B and context Cue X from acquisition (Context BX). Renewal was first tested in a subset of the acquisition context (Context A), followed by a test in the initial acquisition Context AX. Fear responding was assessed by online shock expectancies, startle, and skin conductance.

Results. In line with our predictions, context-cue discrimination training was effective in reducing renewal of shock expectancy in Context A. Moreover, Contexts A and AX revealed similar renewal effects after simple extinction training, whereas renewal was larger in Context AX than A following discrimination training.

Limitations. Startle and skin conductance yielded no reliable acquisition effects, such that the effect of discrimination training on fear responses remains unclear. Test phases were not counterbalanced and may have caused order effects.

Conclusions. The results seem to suggest that conditioned responding became under the control of a specific context cue after context-cue discrimination training.

Introduction

Traumatic events do not occur in isolation. Instead, they take place against a variety of cues (e.g., specific site, smell, sounds) that provide a context for the traumatic experience. These contextual cues may play an important role in retrieving memories for the traumatic event and concomitant fear reactions (Ehlers, 2010). Generalization occurs when fear memories are also triggered by situations unrelated to the trauma and is a core feature of pathological anxiety, such as posttraumatic stress disorder (PTSD) (e.g., American Psychiatric Association, 1994). In itself, fear generalization can be adaptive as it enables one to respond rapidly to impending threat in novel situations. However, it becomes maladaptive when fear reactions persist in situations where intrinsic threat is absent. Indeed, anxiety patients show exaggerated fear reactions compared to the actual level of threat (Rosen & Schulkin, 1998). Although exposure therapy is effective in reducing (i.e., extinguishing) excessive fear reactions (e.g., Öst, 1997), the maintenance of such behaviour change appears delicate: Fear often returns after successful therapy (Rachman, 1989).

One prominent explanation for fear relapse is that fear learning is robust and context independent, while extinction learning is fragile and context dependent (e.g., Bouton, 2002; Craske, 1999). The presumed asymmetry in context dependence between fear and extinction learning is most clearly illustrated by the renewal effect. In a typical renewal experiment, a neutral conditioned stimulus (CS; e.g., a tone) is paired with an aversive unconditioned stimulus (US; e.g., a shock) in one context (Context A) followed by extinction in another context (Context B). Importantly, the context change after acquisition has little impact on conditioned responding to the CS (e.g., Bouton & King, 1983; Harris, Jones, Bailey, & Westbrook, 2000). In contrast, the same sort of context change after extinction of responding by CS alone presentations disrupts extinction performance. That is, conditioned responding renews by presenting the CS again in the context of acquisition (*ABA renewal*) (Bouton & King, 1983; Vansteenwegen et al., 2005) or in a novel context (*ABC renewal*) (Bouton & Bolles, 1979; Effting & Kindt, 2007). Renewal effects indicate that extinction doesn't erase the initial fear memory (CS-US), but rather involves new inhibitory learning (CS-noUS) that is highly context-specific. Outside the extinction context, the fear memory is selectively retrieved and fear renews (Bouton, 2002). Hence, the behavioural effects of exposure (i.e., fear reduction) may be lost when the previously feared object is encountered

outside the therapy context. Insight into processes that decrease renewal effects may therefore boost the efficacy of anti-anxiety therapies on the long term.

To date, experimental research has predominantly focused on enhancing the generality of extinction learning in order to reduce renewal (e.g., Craske et al., 2008). Most relevant to the present study is that extinction in multiple contexts has sometimes shown to attenuate renewal in the context of acquisition or a novel context (Chelonis, Calton, Hart, & Schachtman, 1999; Gunther, Denniston, & Miller, 1998; Vansteenwegen et al., 2007; but see Bouton, García-Gutiérrez, Zilski, & Moody, 2006; Neumann, Lipp, & Cory, 2007; Thomas, Vurbic, & Novak, 2009, Exp 1 and 2). From the view that a context consists of many cues, extinction in multiple contexts might connect extinction learning to a wide variety of contextual cues (see Bouton, García-Gutiérrez et al., 2006). This increases the likelihood that the test context includes cues that are associated with extinction, thereby facilitating retrieval of extinction learning and weakening renewal of fear. However, extinction in multiple contexts seems not the most efficient reduction strategy: Exposure therapy can impossibly cover all cues of the trauma context or future contexts and, thus, the risk for relapse remains. Therefore, a more potent strategy may be to target the robust fear generalization. We propose that focusing on contextual cues that were most relevant for a threatening event may reduce the relevance of the other contextual cues for this event, thereby weakening the generalization of fear.

In order to manipulate the relevance of a context cue at the expense of other cues, two phenomena from the learning literature may be important. Firstly, backward blocking studies show that increasing the relevance of one cue decreases the relevance of other, related cues. Specifically, after pairing a compound consisting of two cues (AX) with an outcome or US, then further pairings of one of the cues (e.g., X) with the outcome/US in absence of the other cue (e.g., A) declines (i.e., blocks) responding to cue A at a later test moment (e.g., Shanks, 1985; Urushihara & Miller, 2010; Wasserman & Berglan, 1998). Second, context discrimination procedures during initial training may enhance the relevance of contexts for responding to a stimulus relative to other contexts (Bouton & Swartzentruber, 1986; Gawronski, Rydell, Vervliet, & De Houwer, 2010). In context discrimination training, stimulus reinforcement in one context (e.g., Context A) is repeatedly alternated with nonreinforcement of the same stimulus in another context (e.g., Context B). Subsequent responding to the stimulus in a novel context (Context C) is less than in the context of reinforcement (Context A). Hence, context discrimination may provide the acquisition context with predictive

value (i.e., relevance) for reinforcement, and, accordingly, acquisition effects become confined to that context.

For the present study, we integrated both strategies (additional acquisition training and context discrimination training) within an extinction procedure. After fear acquisition in one context (Context AX: CS-US), we alternated extinction trials in another context (Context B: CS-noUS) with reacquisition trials accompanied by a contextual cue from acquisition (Context BX: CS-US). Repeatedly alternating between extinction and reacquisition across different contexts may emphasize that this context cue (X) is *the* relevant context for fear learning. We predict that the remaining cues from the acquisition context (A) become less relevant for fear learning and lose their ability to elicit conditioned responding, thereby weakening renewal of fear in Context A. Evidently, re-exposure to actual aversive events in therapy is inconceivable. However, it is well known that previously acquired fear reactions can also be influenced by indirect experiences. Firstly, imaginary rescripting of traumatic events is effective in reducing fear reactions in PTSD patients (e.g., Arntz, Tiesema, & Kindt, 2007; Ehlers, Clark, Hackmann, McManus, & Fennell, 2005). Secondly, reconsolidation studies show that retrieving a fear memory along with amnesic agents (without the aversive event) disrupts the expression of fear memory (e.g., Kindt, Soeter, & Vervliet, 2009; Nader, Schafe, & LeDoux, 2000). Hence, we currently test an experimental method that may be applied by imagery in clinical practice.

The present study examined whether increasing the relevance of a contextual cue for established fear learning by context-cue discrimination training reduces renewal. Participants of two conditions were exposed to differential fear acquisition in Context AX (room picture A and lamp X) by pairing one geometric figure (CS1) with a shock US, while another figure (CS2) was not followed by a shock. Conditions differed for the extinction phase. Condition EXT-only received simple extinction training to both stimuli in Context B (room picture B). Condition EXT-R was exposed to the same amount of extinction trials in Context B. In addition, this condition occasionally received reacquisition trials in which the CS1 was again paired with the shock US. Crucially, reacquisition trials occurred in the joint presence of the extinction context and a discrete cue from the acquisition context (Context BX; room picture B and lamp X). It follows that extinction and cued reacquisition occurred in alternation (*context-cue discrimination training*). To equate the number of trials in both conditions, reacquisition trials were replaced by unreinforced presentations of an irrelevant figure (CS3) in Context B for the EXT-only condition. Renewal was first tested in a subset of the acquisition context

(Context A; room picture A without lamp X) followed by a test in the initial acquisition context (Context AX; room picture A and lamp X). Measures of conditioned fear responding included online expectancy ratings, startle, and skin conductance responding. We hypothesized that context-cue discrimination training would weaken the ability of Context A to elicit renewal of fear. Hence, we expected less renewal in Context A for the EXT-R condition than for the EXT-only condition.

Method

Participants

Forty-eight volunteers with a mean age of 22.48 years ($SD = 3.11$), who were recruited at the University of Amsterdam, participated for course credits or a small payment. Participants were randomly allocated to Condition EXT-R ($n = 24$: 13 men) or Condition EXT-only ($n = 24$: 8 men).

Apparatus

Stimuli. Three blue geometric figures with black outlines served as CSs: A circle with a diameter of 56 mm, a triangle measuring 68 of base and 56 mm of height, and a square of 56 by 56 mm. Contexts consisted of two pictures of a living room or an office (A, B) with or without a floor lamp (X) (see Figure 6.1). Assignment of the room pictures as context cues A or B was counterbalanced. CSs were presented for 8 s in the middle of a computer screen on top of the context picture.

A 2-ms electric shock served as US (see Effting & Kindt, 2007). The startle probe consisted of a 104-dB burst of white noise with an instantaneous rise time presented binaurally for 40 ms through headphones. In addition, a 70-dB broadband background noise was continuously presented.

Measurement. US expectancy ratings were recorded trial-by-trial using a continuous 11-point scale ranging from 0 (*certainly no shock*) through 5 (*uncertain*) to 10 (*certainly shock*). Participants dragged a pointer along the scale with a mouse and confirmed their ratings by a mouse click. The scale was displayed at the bottom of the screen.

Electromyography (EMG) of the left orbicularis oculi muscle in reaction to startle probes and skin conductance responses (SCR) during CSs were measured. The physiological data for both EMG and SCR are not reported because no

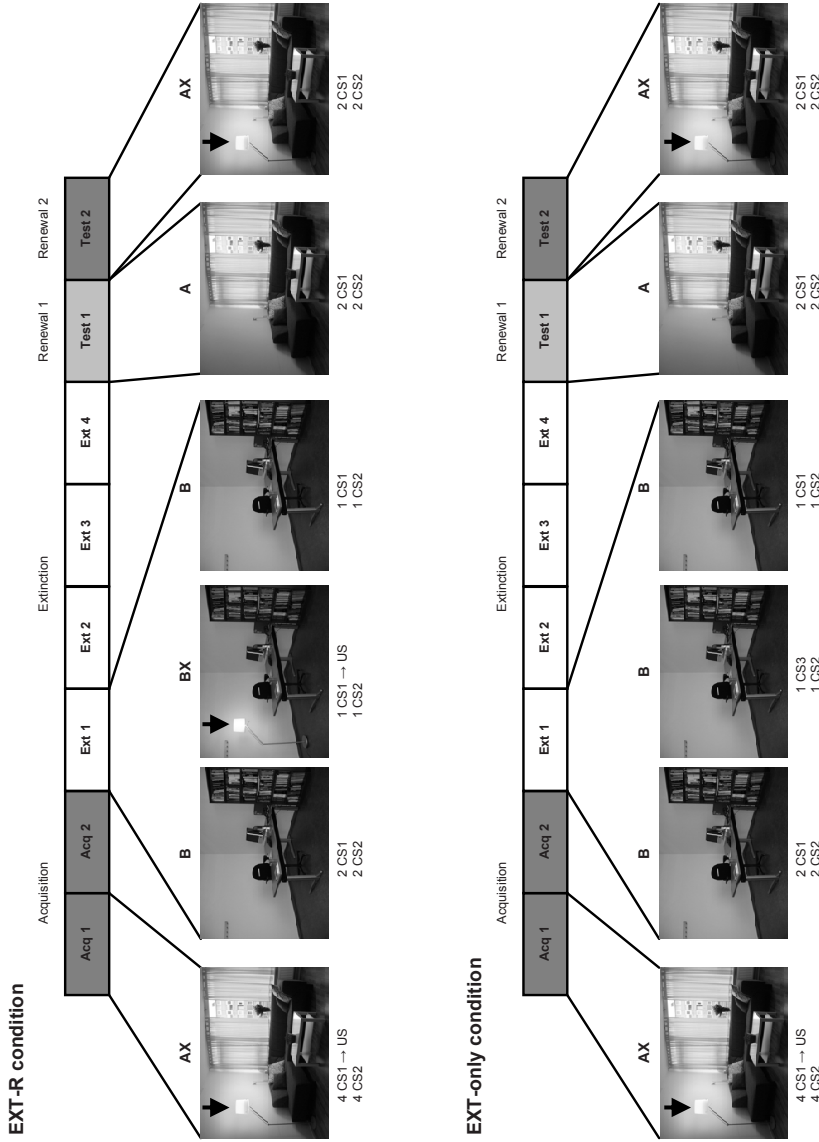


Figure 6.1 Illustration of the experimental design for the EXT-R condition (upper panel) and the EXT-only condition (lower panel). Letters A, B, and X refer to the context manipulations consisting of a room picture (A or B) and a floor lamp (X). Context cue X is indicated with a black arrow. CS1, CS2, and CS3 were the conditioned stimuli, US was the unconditioned stimulus.

reliable effects were observed. That is, for the EMG data, no reliable acquisition was obtained in Condition EXT-R and, for the SCR data, we did not observe a reliable acquisition effect across conditions. Accordingly, the methods for recording EMG and SCR are only briefly described. The physiological data are, however, available upon request.

Procedure

After attachment of the electrodes, shock intensity was individually selected on a level defined by participants as definitely uncomfortable, but not painful. Participants were orally explained that different figures would be presented to them. They were instructed to observe the figures carefully as one of the figures would sometimes be followed by a shock, while other figures would never be followed by a shock. Participants were asked to predict shock delivery during each figure by using the rating scale. Participants were individually tested in a sound-attenuated room with dimmed light, adjacent to the experimenter's room.

There were four phases: acquisition, extinction and two renewal tests (see Figure 6.1). During the *acquisition phase*, participants received eight trials of both CS1 and CS2 divided into two blocks of four trials of each stimulus (4 CS1, 4 CS2). The circle and triangle served as CS1 and CS2, respectively, with assignment counterbalanced across participants. The US co-terminated with the CS1. Intertrial intervals (ITIs) consisted of a fixed pretrial interval of 10 s and a variable posttrial interval of 16, 18, or 20 s with a mean of 18 s. In each block, order of trial and posttrial interval was randomized with the limitation that no more than two trials or posttrial intervals of the same type could be administered consecutively. For both conditions, acquisition occurred in Context AX (room A and lamp X).

During the *extinction phase*, participants in the EXT-R condition received 16 trials of both CS1 and CS2 divided into four blocks of four trials (4 CS1, 4 CS2). Each block consisted of an extinction subblock including three nonreinforced trials (3 CS1, 3 CS2) and a reacquisition subblock (1 CS1, 1 CS2), during which the CS1 was again followed by the US, but not the CS2. This resulted in a total of 12 extinction trials and four reacquisition trials for each stimulus type. Extinction trials were administered in Context B (room B), while cued reacquisition trials were presented in the joint presence of the extinction context and a context cue from acquisition, Context BX (room B and lamp X). Presentation of Cue X started 10 s before CS onset (i.e., pretrial interval) and continued until 16-20 s after CS offset (i.e., posttrial interval). To allow for discrimination between extinction and cued

reacquisition trials, the position of a cued reacquisition trial within each four-trial block was fixed: on the 3rd, 4th, 2nd, and 1st position in four blocks, which corresponds with trials 3, 8, 10, and 13, respectively. Participants in the EXT-only condition received a similar presentation schedule, with two exceptions. First, within each block, a novel subblock including one nonreinforced presentation of novel CS3 and CS2 (1 CS3, 1 CS2) replaced the reacquisition subblock. Second, all trials, including novel trials, were presented in Context B (room B).

Each *renewal test phase* consisted of a block of two nonreinforced trials of both CS1 and CS2. The first test was conducted in a subset of contextual cues from acquisition, Context A (room A without lamp X). The second test occurred in original acquisition Context AX (room A including lamp X). During extinction and cued reacquisition subblocks as well as during test blocks, characteristics for trial and ITI order were similar as to acquisition with the following exception. The first two trials in extinction (CS1, CS2) and the test trials were counterbalanced: Half of the participants started extinction with CS1 followed by CS2 and received both test phases in the order: CS1, CS2, CS2, CS1. The other half started extinction with CS2 followed by CS1, while trials in both test phases were ordered as CS2, CS1, CS1, CS2. All phases started with a 5-s acclimation period during which the context but no stimuli were presented.

Prior to acquisition, 10 startle probes were presented to habituate the startle response. To assess context conditioning, two startle probes were delivered in each phase before CS presentations. To assess cue conditioning, six startle probes were administered during each experimental block: Two probes were delivered at 5 or 7 s after CS onset (2 CS1, 2 CS2) and two probes at 11 or 15 s after CS offset (2 ITI). Additionally, on the 1st and 4th extinction block, three probes were presented during the reacquisition subblock (EXT-R) or the novel subblock (EXT-only): 1 CS1/1 CS3, 1 CS2, and 1 ITI.

Afterwards, participants were asked to rate the valence of CSs on an 11-point scale labelled from -10 (*negative*) to 10 (*positive*). Additionally, participants evaluated the US and the startle probe on two characteristics. Pleasantness was rated on an 11-point scale anchored by *unpleasant* (-10) and *pleasant* (10) and intensity was indicated on a 5-category scale with the labels *weak*, *moderate*, *intense*, *enormous*, and *unbearable* (scored as 1 to 5).

Statistical analysis

Rated expectations of the US were measured during CS presentation. In case no rating was recorded, the average rating level of the last 2 s of a CS presentation was used. Expectancy ratings were analyzed by CS-type \times Trial \times Condition mixed analyses of variance (ANOVA) with CS-type and trial as within-subjects factors. The factor CS-type always included two levels (CS1/CS3, CS2), just like the factor condition (EXT-R, EXT-only), whilst levels of the factor trial varied depending on the exact analysis. US, CS, and startle probe characteristics were analyzed by 2 Condition (EXT-R vs. EXT-only) factorial ANOVAs. The results most pertinent to the hypotheses are reported. Greenhouse-Geisser corrections were applied in case when the sphericity assumption was violated. Adjusted p -values are reported, but accompanied by nominal degrees of freedom.

Results

There were no differences between conditions in selected US intensity ($M_{\text{overall}} = 16.50$ mA; $SD_{\text{overall}} = 11.00$), $F < 1$. Figure 6.2 displays mean US expectancy ratings per condition. Participants readily acquired differential shock expectancies to CS1 and CS2 during acquisition, as was indicated by a significant CS-type \times Trial (trial 1-8) interaction, $F(7, 322) = 146.74$, $p < .001$, $\eta_p^2 = .76$, including the linear trend, $F(1, 46) = 592.85$, $p < .001$, $\eta_p^2 = .93$. Unexpectedly, overall ratings were somewhat higher for Condition EXT-R than for Condition EXT-only with the difference approaching significance, $F(1, 46) = 3.92$, $p = .05$, $\eta_p^2 = .08$. Nevertheless, the pattern of acquisition did not differ between conditions (CS-type \times Trial \times Condition: $F < 1.53$).

A context switch after acquisition caused a decline in differential ratings from the last acquisition trial (trial 8) to the first extinction trial (trial 1) (CS-type \times Trial: $F(1, 46) = 64.42$, $p < .001$, $\eta_p^2 = .58$) (see Figure 6.2). Post hoc comparisons showed that ratings of the CS1 decreased, $F(1, 46) = 20.44$, $p < .001$, $\eta_p^2 = .31$, whereas ratings of the CS2 increased, $F(1, 46) = 63.31$, $p < .001$, $\eta_p^2 = .58$. Nevertheless, CS1/CS2 differentiation was still highly significant on the first extinction trial, $F(1, 46) = 63.27$, $p < .001$, $\eta_p^2 = .58$. The absence of a CS-type \times Trial \times Condition interaction, $F < 1.61$, suggested no difference in generalization decrement between conditions.

On extinction trials, both conditions showed a comparable loss of differential expectancy ratings to CS1 and CS2, as shown by a significant CS-type \times Trial (trial 1-2, 4-7, 9, 11-12, 14-16) interaction, $F(11, 506) = 28.43$, $p < .001$, η_p^2

= .38, and linear trend, $F(1, 46) = 46.32, p < .001, \eta_p^2 = .50$, and the absence of a CS-type \times Trial \times Condition interaction, $F < 1$ (see Figure 6.2).

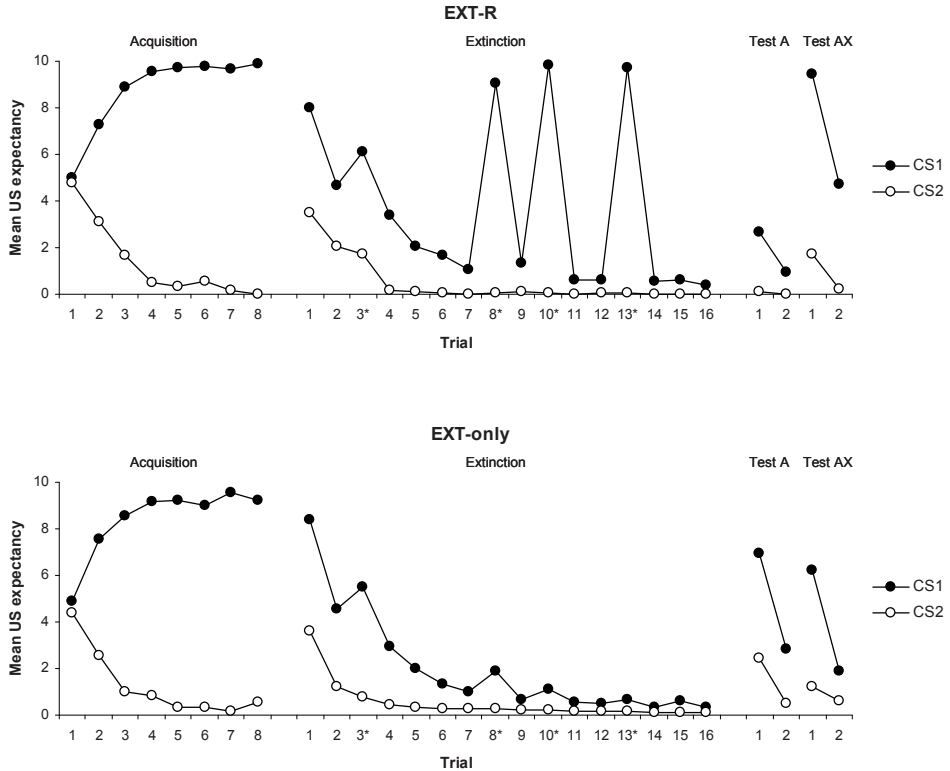


Figure 6.2 Mean US expectancy ratings for CS1 and CS2 during acquisition, extinction, and tests in Contexts A and AX separately for the EXT-R condition (upper panel) and the EXT-only condition (lower panel). The reacquisition trials (EXT-R) and the novel trials (EXT-only) administered during extinction are indicated with an asterisk * (trial 3, 8, 10, and 13). Note that on novel trials (EXT-only) CS1 was replaced by CS3.

On reacquisition trials⁴, shock expectancies to CS1 recurred rapidly for the EXT-R condition. By contrast, ratings to CS3 extinguished on novel trials for the EXT-only condition. This was indicated by a significant CS-type \times Trial (trial 3, 8, 10, 13) \times Condition interaction, $F(3, 138) = 76.39, p < .001, \eta_p^2 = .62$. Post hoc analyses showed that differential ratings (CS1/CS2) progressively increased for Condition EXT-R (CS-type \times Trial: $F(3, 69) = 42.99, p < .001, \eta_p^2 = .65$, and linear

⁴ Condition EXT-only received nonreinforced CS3 presentations during reacquisition trials.

trend, $F(1, 23) = 49.16, p < .001, \eta_p^2 = .65$), whereas differential ratings (CS3/CS2) gradually decreased for Condition EXT-only (CS-type \times Trial: $F(3, 69) = 33.86, p < .001, \eta_p^2 = .60$, and linear trend, $F(1, 23) = 66.70, p < .001, \eta_p^2 = .74$) (see Figure 6.2).

Renewal was qualified as an increase in responding to CS1 relative to CS2 from the last extinction trial (trial 16) to the first test trial (trial 1). As predicted, a return to a subset of contextual cues from acquisition (Context A) after extinction in Context B produced weaker renewal in Condition EXT-R than in Condition EXT-only, as was indicated by a CS-type \times Trial \times Condition interaction that approached significance, $F(1, 46) = 3.91, p = .05, \eta_p^2 = .08$ (see Figure 6.2). Post hoc analyses revealed that not only the increase for CS1 ratings but also the increase for CS2 ratings was significantly reduced for Condition EXT-R compared to Condition EXT-only (Trial \times Condition: $F_{CS1}(1, 46) = 21.35, p < .001, \eta_p^2 = .32$, and $F_{CS2}(1, 46) = 18.10, p < .001, \eta_p^2 = .28$, respectively). Additional post hoc analyses showed, however, that renewal was not completely abolished in Context A after context-cue discrimination training, as indicated by significant renewal effects for both conditions (CS-type \times Trial: $F_{EXT-R}(1, 23) = 10.61, p < .01, \eta_p^2 = .32$, and $F_{EXT-only}(1, 23) = 28.08, p < .001, \eta_p^2 = .55$, respectively).

In contrast to Context A, testing in the original acquisition Context AX resulted in significantly stronger renewal for the EXT-R condition than for the EXT-only condition (CS-type \times Trial \times Condition: $F(1, 46) = 7.63, p < .01, \eta_p^2 = .14$). Post hoc analyses showed a greater increase in CS1 ratings from the last extinction trial in Context B (trial 16) to the first test trial in Context AX (trial 1) for Condition EXT-R relative to Condition EXT-only (Trial \times Condition: $F(1, 46) = 15.23, p < .001, \eta_p^2 = .25$), but no difference between conditions for CS2 ratings (Trial \times Condition: $F < 1$).

Comparison of renewed differential responding in Context A (trial 1) and Context AX (trial 1) between conditions indicated that renewal was context dependent for Condition EXT-R, but not for Condition EXT-only (CS-type \times Trial \times Condition: $F(1, 46) = 15.26, p < .001, \eta_p^2 = .25$). Post hoc analyses showed smaller differential responding in Context A than in Context AX for Condition EXT-R (CS-type \times Trial: $F(1, 23) = 26.55, p < .001, \eta_p^2 = .54$), whereas differential responding did not differ across contexts for Condition EXT-only (CS-type \times Trial: $F < 1$).

After the experiment, participants rated the CS1 as more negative following context-cue discrimination than following simple extinction ($M_{EXT-R} = -6.42, SD_{EXT-R} = 3.12; M_{EXT-only} = -3.42, SD_{EXT-only} = 5.26$), $F(1, 46) = 5.58, p = .02, \eta_p^2 =$

.11. In contrast, the CS3 was rated more positively after simple extinction ($M_{\text{EXT-only}} = 5.50$, $SD_{\text{EXT-only}} = 5.01$) than after context-cue discrimination ($M_{\text{EXT-R}} = 0.83$, $SD_{\text{EXT-R}} = 2.28$), $F(1, 46) = 17.24$, $p < .001$, $\eta_p^2 = .27$. No group differences were obtained regarding CS2 valence ratings ($M_{\text{overall}} = 7.54$, $SD_{\text{overall}} = 3.26$), $F < 1$, or in the way participants experienced the US and the startle probe, $F_s < 2.90$. Both US and startle probe were rated as fairly unpleasant ($M_{\text{US-overall}} = -5.54$, $SD_{\text{US-overall}} = 2.81$; $M_{\text{probe-overall}} = -5.75$, $SD_{\text{probe-overall}} = 3.37$) and intense ($M_{\text{US-overall}} = 2.83$, $SD_{\text{US-overall}} = 0.52$; $M_{\text{probe-overall}} = 2.98$, $SD_{\text{probe-overall}} = 0.67$).

Discussion

The present study examined whether context-cue discrimination training during extinction can weaken renewal. First, the control group that received simple extinction in a context different from acquisition, showed clear renewal of shock expectancy upon returning to only a subset of contextual cues from acquisition. This finding extends the generality of the renewal effect. Second and most important, occasionally presenting reacquisition trials featured by a context cue from acquisition during extinction (context-cue discrimination training) weakened the renewal effect in the subset from the acquisition context. Third, context-cue discrimination training unexpectedly increased renewal of shock expectancy in the original acquisition context relative to simple extinction training. Fourth, the strength of renewal depended on the test context following context-cue discrimination training, but not following simple extinction training. In sum, the results suggest that context-cue discrimination training during an extinction procedure confines conditioned responding to a specific context cue, thereby reducing the recovery of conditioned responding by other, related context cues.

No reliable acquisition effects were obtained for physiological measures (startle, skin conductance). Therefore, the present findings do not permit any conclusions regarding conditioned *fear* responses. The lack of conditioning for startle may be due to the startle procedure: Only some of the CS trials were probed and the moment of a CS probe varied. Although such a procedure can induce reliable conditioning (Alvarez, Johnson, & Grillon, 2007), it may have caused unpredictability of probe delivery, thereby elevating fear to both conditioned stimuli and thus leaving less room for differentiation. In a similar vein, elevated fear to stimuli may also have impeded the acquisition of discriminative skin conductance responding.

Remarkably, both test contexts (Contexts A and AX) unveiled clear and similar renewal effects after simple extinction training. Hence, returning to only a component of the original acquisition context after extinction in another context was sufficient to reactivate conditioned shock expectancies. This is in line with the proposed asymmetry in generalization between fear and extinction learning: Fear learning generalizes easier to different contextual cues than extinction learning (e.g., Bouton, 2002). In contrast to the simple extinction condition, tests contexts revealed different renewal effects in the reacquisition condition: Renewal was larger in Context AX than in Context A, suggesting that conditioned responding became dependent on the presence of the specific context cue (X) after discrimination training.

With regard to the mechanism underlying the reduction of renewal by context-cue discrimination training, several speculations can be put forward. To begin with, it may be that initial context-free fear learning became context dependent by context-cue discrimination training. Such an explanation implies updating of an existing fear memory with information about the context. Recent research indicates that consolidated fear memories are not fixed, but may be influenced when retrieved (e.g., Kindt et al., 2009; Nader et al., 2000). Retrieval of a previously stable fear memory returns it into a plastic state before it is reconsolidated again (Lee, 2009). Hence, reconsolidation may provide an opportunity for a context-free memory to become context dependent. However, one may question whether the current procedure allowed for reconsolidation as this involves a subtle timing process (e.g., Schiller et al., 2010).

Alternatively, context-cue discrimination training may have endowed the specific context cue with (positive) occasion setting properties. Positive occasion setters modulate responding to other stimuli. That is, they signal that other stimuli will be followed by an aversive outcome (e.g., Holland, 1992). An explanation in terms of occasion setting predicts that the presence of the context cue is necessary for eliciting conditioned responding. In line with this interpretation, shock expectancies were higher in the *presence* than in the *absence* of the context cue used for discrimination training.

Despite the absence of physiological evidence, we believe that the current observation of reduced shock expectancies by context-cue discrimination training may be clinically relevant for several reasons. First, current learning models of anxiety assume that expectancy of aversive events underlies the development and maintenance of anxiety disorders (e.g., Craske et al., 2008). Second, recent developments in conditioning emphasize the role of reasoning processes and

contingency awareness in associative learning, which give rise to propositional knowledge. The belief that a cue will lead to a harmful event can activate fear responses (Mitchell, De Houwer, & Lovibond, 2009). However, there is mixed evidence whether anticipation of an aversive event is sufficient for fear responses to occur (Kindt et al., 2009; Soeter & Kindt, 2010; Weike, Schupp, & Hamm, 2007). Hence, it may well be possible that we only changed declarative knowledge without producing a shift in the fear system.

The context-cue discrimination procedure unintentionally increased negative valence ratings to the threat stimulus (CS1) relative to a simple extinction procedure. This finding was not due to group differences in selected shock intensity. Arguably, additional pairings with the shock rendered the threat stimulus (CS1) more negative. Despite this negative connotation, discrimination training weakened renewal of shock expectancy (in Context A). Hence, expectancy ratings were not driven by evaluative ratings, but rather by inferential learning: Learning about (context) cues that predict the occurrence or non-occurrence of an aversive event. However, this also raises the question of whether context-cue discrimination training affected declarative knowledge rather than the fear system.

Irrespective of the exact mechanism, the present results suggest that increasing the informational value of one cue from acquisition reduced the ability of the remaining cues to elicit renewal. Recently, increasing the predictability of a threatening event showed to be an effective strategy in reducing contextual anxiety (Fonteyne, Vervliet, Hermans, Baeyens, & Vansteenwegen, 2009, 2010). It was argued that providing a discrete cue that *predicts* threat simultaneously signals the *absence* of threat when this cue is not present. A similar account may apply to the current findings. Learning to differentiate between situations in which a cue predicts danger or safety may impede the generalization of cued fear. The present findings also show similarities with the concept of contextualization of trauma memories as a strategy for reducing re-experiencing symptoms in PTSD patients (Ehlers & Clark, 2000). In this approach, contextualization refers to learning that similar cues (CS) can have different meanings in various situations. Differentiating between safe and unsafe situations is thought to prevent unnecessary triggering of the trauma memory.

A limitation of the present study is that the renewal tests were not counterbalanced. Always testing in Context A before testing in Context AX may have caused order effects. For instance, in the simple extinction condition, nonreinforced stimulus presentations (i.e., extinction) in the first test Context A may have lowered this context's ability to elicit renewal. Given that Context A was

also part of the second test Context AX, renewal in Context AX may have been smaller relative to testing in this context at first. The unexpected finding that context-cue discrimination training enhanced renewal in the original acquisition context (Context AX) relative to simple extinction training may therefore reflect an order effect. As we were primarily interested in renewal reduction in Context A, we did not counterbalance the test phases. However, this may have confounded responding in the second test Context AX.

Despite this limitation, we believe that the present study provides a new perspective on the prevention of relapse after treatment. The current findings show that context-cue discrimination training during extinction reduced recovered expectancies of an aversive event. An intriguing question for future research is whether the context cue used for discrimination training must be identical to the cue that was present during acquisition. If similarity is not required, this would enlarge clinical applications as patients do not always accurately remember the context features that surrounded the trauma (Christianson, 1992).