Published in final edited form as:

Behav Ther. 2011 June ; 42(2): 153–169. doi:10.1016/j.beth.2010.06.002.

S-R Associations, Their Extinction, and Recovery in an Animal Model of Anxiety: A New Associative Account of Phobias Without Recall of Original Trauma

Mario A. Laborda and

State University of New York, Binghamton, and Universidad de Chile

Ralph R. Miller

State University of New York, Binghamton

Abstract

Associative accounts of the etiology of phobias have been criticized because of numerous cases of phobias in which the client does not remember a relevant traumatic event (i.e., Pavlovian conditioning trial), instructions, or vicarious experience with the phobic object. In three lick suppression experiments with rats as subjects, we modeled an associative account of such fears. Experiment 1 assessed stimulus-response (S-R) associations in first-order fear conditioning. After behaviorally complete devaluation of the unconditioned stimulus, the target stimulus still produced strong conditioned responses, suggesting that an S-R association had been formed and that this association was not significantly affected when the outcome was devalued through unsignaled presentations of the unconditioned stimulus. Experiments 2 and 3 examined extinction and recovery of S-R associations. Experiment 2 showed that extinguished S-R associations returned when testing occurred outside of the extinction context (i.e., renewal) and Experiment 3 found that a long delay between extinction and testing also produced a return of the extinguished S-R associations (i.e., spontaneous recovery). These experiments suggest that fears for which people cannot recall a cause are explicable in an associative framework, and indicate that those fears are susceptible to relapse after extinction treatment just like stimulus-outcome (S-O) associations.

Recent epidemiological studies have shown a high prevalence of specific phobias, reaching levels as great as 10% for the last 12 months and 16% in a lifetime (Alonso et al., 2004; Becker et al., 2007; Somers, Goldner, Warach, & Hsu, 2006; Stinson et al., 2007). These data represent the prevalence of the four types of phobias specified by the fourth edition of the Diagnostic and Statistical Manual of Mental Disorders (i.e., animal, natural, blood-injection, and situational types; *DSM-IV*, American Psychiatric Association, 1994) in American and European populations. In Somers et al.'s (2006) review, specific phobias accounted for almost one third of the prevalence of all anxiety disorders (total anxiety disorder for the last 12 months was 10.6% and for a lifetime 16.6%). To put this in perspective, Alonso et al. (2004) reported that the prevalence of anxiety disorders is almost half of the prevalence of all mental disorders in the population. Considering the

© 2010 Published by Elsevier Ltd on behalf of Association for Behavioral and Cognitive Therapies.

Address correspondence to Ralph R. Miller, Ph.D., Department of Psychology, SUNY- Binghamton, Binghamton, NY 13902-6000; rmiller@binghamton.edu..

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

pervasiveness of these disorders, it is important to understand their etiology towards finding ways to treat them.

Associative Accounts for the Etiology of Phobias

Associative theories of the etiology of anxiety disorders began with Pavlov's (1927) discovery of so-called experimental neurosis. Pavlov showed that different experimental manipulations (e.g., directly applied aversive stimulation and very difficult discriminations) produced laboratory-induced emotional reactions in dogs. Importantly, these experiments represent one of the first known experimental demonstrations of learned emotional responses and constitute the first associative model for the etiology of anxiety disorders. Later models of the etiology and treatment of anxiety disorders were developed based on this early research (Kazdin, 2000; Wolpe & Plaud, 1997; see Wolpe, 1958, as an example).

After demonstrating learned emotions in nonhumans, the next step in understanding the acquisition of fear and anxiety from an associative point of view was to empirically test whether emotions could be learned in humans. Watson and Rayner (1920) were pioneers in demonstrating that human infants can learn emotions by stimulus association. More specifically, pairing a rat and a loud noise seven times was enough for Albert B. (an 11-month-old) to show fear of the rat. In this model, the phobic object (i.e., the rat) does not initially provoke a fear response or play the role of a conditioned stimulus (CS). But when the presentation of the rat was followed by an unconditioned stimulus (US; i.e., the loud noise) that naturally provokes a fear response, the subject associates them and the CS begins eliciting responses similar to those provoked by the US. Based on their research, Watson and Rayner suggested, "It is probable that many of the phobias in psychopathology are true conditioned emotional reactions ..." (p. 14).

This simple conditioning model was fundamental for the development of more modern associative accounts of the etiology of fear and phobias. In recent years, Mineka and colleagues (e.g., Mineka & Oehlberg, 2008; Mineka & Sutton, 2006; Mineka & Zinbarg, 2006) have proposed a modified conditioning model known as the contemporary learning account of the etiology of fears and phobias. Like earlier models, this associative account explains the etiology of phobias based upon current evidence from basic research on Pavlovian conditioning, but it also includes factors to account for individual differences in associative learning, personality/temperamental factors, and evolutionary variables (for a recent review of the role of conditioning in understanding the development of phobias, see Field, 2006; Merckelbach, de Jong, Muris, & van den Hout, 1996).

Common Criticisms of Associative Accounts for the Etiology of Phobias

Since their inception, traditional associative accounts have been criticized on four major points, most of which derive from an overly simplistic view of associative learning. These criticisms include: (a) many individuals with phobias do not remember a traumatic conditioning event; (b) a small number of nonrandom stimuli account for most of the phobias; (c) not all aversive experiences provoke phobias; and (d) phobias do not extinguish in the same manner as aversive associations in the laboratory (Fyer, 1998; for related criticisms, see Merckelbach et al., 1996). Contemporary associative models provide explanations for three of these four critiques. The nonrandomness of the phobic stimuli has been partially explained by considering evolutionary constraints in associative learning (e.g., Öhman & Mineka, 2001; Seligman, 1971). The observation that not all individuals develop phobias after aversive experiences is readily explained by individual differences in associative learning (e.g., Mineka & Zinbarg, 2006). The literature concerning associative models of exposure therapy and relapse has helped to explain why extinction in clinical settings does not always appear to mirror extinction in the laboratory with animal behavior

(e.g., Bouton, 2000, 2002). In our view, the one criticism of the associative account that has not been *properly* addressed is the fact that many patients do not recall any history of aversive conditioning events (Fyer, 1998). Moreover, Fyer argued that even if we can verify a traumatic conditioning event in these patients, it is still necessary to explain why they do not remember the conditioning event from which the fear arose.

Some Possible Accounts of Fears Without Recall of Causes

The literature contains several potential accounts of fears without recall of causes. For example, it has been proposed that these fears can be acquired through learning without conscious awareness (e.g., Esteves, Dimberg, & Öhman, 1994; Olsson & Phelps, 2004), and that simple forgetting, childhood amnesia, vicarious learning, or instructional acquisition may be good explanations of some cases of fears reported as not having causes (e.g., Mineka & Sutton, 2006). Additionally, Davey and colleagues (e.g., Davey, 1992; Davey, de Jong, & Tallis, 1993) proposed a US reevaluation process to explain why some fears are reported as not having causes. In this account, associations between neutral stimuli and/or between neutral stimulus and mild USs can be enhanced at a later time if the US itself is reevaluated as highly aversive, perhaps through instructional information or real experience with a more intense US. Because the more intense US representation has never been paired with the target CS, the memory of this association is presumed to be weak. This account shares similarities with the argument presented by Cook and Mineka (1987), who suggested that second-order associations can explain this type of fear (in a second-order conditioning situation, a target CS1 acquires behavioral control after having been paired with a CS2 which has been previously paired with the US). In this situation, the target cue (CS2) supports behavioral control even when it has never been directly paired with the US.

Field (2006) has recently introduced another associative account for fears without memory of causes, which is based on evidence suggesting that associations do not need to be between actual events but between mental representations of these events (e.g., Dwyer, 2003). For him, a “stimuli can be associated with aversive USs without it ever having occurred in the presence of that US. All that is required is that they are experienced in the presence of a representation of an aversive US” (p. 864). Field proposed that in this situation a person would not have memory of the co-occurrence of the CS and the US because they were actually never presented together. Note that this account stresses the role of cognitions in the contemporary conditioning theory of anxiety. In this view, cognitions are conceptualized as inner behavior and they follow the same rules than any other behavior.

Finally, from a nonassociative perspective, the absence of recall of conditioning experiences in phobic patients is expected because conditioning is not thought to be critical in acquiring fears (e.g., Poulton & Menzies, 2002). According to this account, fears are mostly innate and phobic reactions are caused by a failure in habituating these fears during development. All of the above may well be factors in some cases of no verbal recall of the basis of fears, but here we pursue another possibility.

Memory of Conditioning Events

Based on studies in which participants are asked if they remember any previous experience that they think is the cause of their fears, three different causes have been suggested. These include direct conditioning experiences with the phobic object, vicarious acquisition of the fear, and instructional acquisition. Importantly, however, there are a number of cases in which participants do not remember any cause of their phobic reactions (McNally & Steketee, 1985; Menzies & Clarke, 1993; Murray & Foote, 1979; Ost & Hugdahl, 1981, 1983; Rimm, Janda, Lancaster, Nahl, & Dittmar, 1977). The evidence is highly divergent among studies, but it suggests that between 18.0% and 57.5% of the cases studied with

different specific phobias and with different populations reported a direct conditioning event as the cause of their fears. In contrast, between 15.0% and 68.0% of the cases reported not remembering any cause of their fears. Considering those numbers, it is clear that an explanation of why people are afraid of something without remembering any cause is a missing component in an associative account of the etiology of fears and phobias. Mineka and Oehlberg (2008) indicated that the early conditioning models of phobias were unable to account for many of the cases of specific phobias, and that is why indirect associative pathways have been studied (e.g., vicarious and instructional acquisition; for further discussion, see the three pathway model of the etiology of fear by Rachman, 1977, 1990). However, it is not clear why something learned by vicarious or instructional processes would not be remembered as a cause of the phobic reaction. Thus, the associative account still fails to explain some patients' failure to remember the source of phobias.

An Associative Account for Phobias Without Recall of Causes

Rizley and Rescorla (1972; see also Dollard & Miller, 1950; Mineka, 1985) suggested that in some experimental preparations in aversive Pavlovian conditioning, "the origin of the fear may have long ago lost its effect while secondary stimuli continue to produce anxiety" (p. 11). This statement is supported by the results of a series of articles in which Rescorla showed that a second-order CS can maintain its behavioral control even when the first-order CS and the US have lost their capacity to elicit fear (Rizley & Rescorla, 1972; Rescorla, 1973; Rescorla, 1974). In a typical second-order fear conditioning experiment, a CS (CS1) is first paired with an aversive US (CS1-US). Then, the CS1 is presented contiguously with a second CS, CS2 (CS2-CS1). After this treatment, both CS1 and CS2 elicit a fear response despite CS2 never having been directly paired with the US. In this situation, responding to CS2 can be explained in at least three different ways. First, CS2 could be directly associated with CS1 (stimulus-stimulus association; S-S) and, when presented alone, the representation of CS1 is activated and a conditioned response is elicited because CS1 has an association with the US (stimulus-outcome association; S-O), which produces responding. In other words, CS1 mediates responding to CS2. Second, CS2 could develop a direct association with the representation of the US elicited by CS1 when CS2 and CS1 were paired (S-O association). Therefore, when presented alone, the representation of the US is activated and a response is elicited because the US representation unconditionally produces responding. Third, CS2 could be associated with the conditioned fear response (CR) elicited by CS1 during CS2-CS1 pairings (stimulus-response association; S-R). Notably, the two first possible explanations for CS2's behavioral control rely directly or indirectly on an S-O association and that the S-R explanation does not. Rescorla (1973; Exp. 3) disambiguated these possibilities in a critical experiment using rats as experimental subjects in a conditioned suppression preparation. In Phase 1 of his experiment, all subjects received first-order fear conditioning consisting of pairing of a CS (CS1) with a loud aversive horn (US). Later, in Phase 2, a second-order association was formed when subjects received pairing of a second CS (CS2) with the CS trained in Phase 1 (CS2-CS1), which, as stated above, usually results in behavioral control by CS2 even when it has never been paired directly with the US. Finally, half of the animals received devaluation of the outcome representation by repeatedly presenting the US alone (i.e., habituation to the US). After the US was devalued, a deterioration of the conditioned responses elicited by CS1 was evident compared with those animals that did not receive US devaluation treatment. However, responding to CS2 was not significantly affected, suggesting that a CS2-fear response (S-R) association was formed during second-order fear conditioning, which is not affected by US devaluation. These results are open to at least two criticisms: (a) the potential of the US to unconditionally provoke responding after the devaluation treatment was not directly assessed; if the US was not completely devaluated, then it is still possible that responding to CS2 depends on residual S-O associations; and (b) the reduction in responding to CS1 after

US devaluation was not complete, which introduces the possibility of S-R associations contributing to first-order conditioning and CS2-CS1 associations contributing to responding to CS2.

As proposed previously (Dollard & Miller, 1950; Mineka, 1985; Rizley & Rescorla, 1972), it is possible that a fear can be maintained even without a trace of the original S-O association. S-R associations (which need not be established through second-order conditioning) can account for fear of a CS without recall of its causes, that is, effective USs. But more controlled studies are needed to properly assess this possibility.

An Associative Model of Exposure Treatment and Relapses

In a related line of research, experimental extinction of Pavlovian conditioning has been proposed as an associative model of exposure therapy (e.g., Bouton, 2000; Bouton & Nelson, 1998). The basic finding in extinction is that, after an association between a CS and US has been formed through contiguous pairings, presentations of the CS by itself decreases its behavioral control. In the case of exposure treatment for a specific phobia, the phobic object is considered a CS, which, if repeatedly presented without the US, will decrease its potential to elicit fear responding. This associative model has received extensive attention from researchers, principally because exposure therapy is one of the most empirically supported treatments in psychotherapy (Chambless et al., 1996; Chambless & Ollendick, 2001). However, exposure treatment is not perfect and relapse after treatment is common (Craske, 1999). Importantly, relapse also has associative models. Evidence indicates that extinction does not erase the original association between a CS and a US, but creates a new inhibitory-like association in which the context plays an important role (for reviews, see Bouton, 1993, 2000, 2004). For example, recovery from extinction, which models relapse, occurs when a long delay between extinction trials and testing is imposed (i.e., spontaneous recovery; e.g., Brooks & Bouton, 1993; Pavlov, 1927; Robbins, 1990), and when testing occurs outside the extinction context (i.e., renewal; e.g., Bouton & Bolles, 1979; Bouton & King, 1983; Bouton & Ricker, 1994). Renewal and spontaneous recovery are some of the phenomena that suggest extinction does not erase the CS-US association, and they provide associative models of relapse after exposure therapy.

The Present Series of Experiments

Towards illuminating why some anxiety patients fail to recall a precipitating conditioning event, this series of experiments was designed to look for S-R associations in first-order fear conditioning with conservative controls using rats as experimental subjects, and to evaluate the possibility of recovery of those associations once they were extinguished. All three experiments reported here used a lick suppression preparation in which water-deprived rats received pairings of a CS (i.e., tone) and a US (i.e., aversive loud clicks). At test, we evaluated the level of fear responses to the CS. All rats were drinking water at the onset of the CS, which disrupted the drinking behavior. Latency to resume drinking water during the CS was our index of conditioned fear (i.e., longer delays in resume drinking imply stronger fear to the CS). This testing situation can be thought of as simulating a situation in which phobic patients encounter feared objects (i.e., CSs) and their ongoing behavior is disrupted, with time to resume their ongoing activities serving to index the magnitude of fear of the phobic object.

In Experiment 1 we evaluated the possibility of S-R associations using the US devaluation procedure employed by Rescorla (1973), but unlike Rescorla we directly assessed the effectiveness of this procedure by testing some subjects on the US with and without US devaluation. Devaluation of the US may either weaken the outcome-response (O-R) association or create an outcome-no response association that competes with the O-R

association. But in either case, activation of the representation of the outcome no longer leads to responding. Hereafter, we will simply refer to US devaluation as undermining responses dependent on the S-O association. Experiment 2 tested whether extinguished S-R associations were susceptible to ABC renewal, a recovery of extinguished CRs produced when acquisition, extinction, and testing each take place in different contexts (e.g., Bouton & Bolles, 1979). Finally, Experiment 3 tested if extinguished S-R associations were susceptible to spontaneous recovery.

Experiment 1: S-R Association

The present experiment evaluated a new associative account for the etiology of phobias without recall of the original trauma. The logic behind this account is that conditioned responses (i.e., fear) to CS (i.e., phobic object) can persist even after the US itself (i.e., original trauma) is no longer capable of provoking unconditioned responses. Thus, as stated previously, if the behavioral control of the US is eliminated through a US devaluation procedure, and the CS continues to support responding, an S-R association (i.e., phobic object-fear response association) could be responsible for this conditioned responding, thereby modeling fears without memory of the original trauma.

More specifically, Experiment 1 evaluated the role of an S-R association in first-order fear conditioning using a US devaluation procedure similar to the one used by Rescorla (1973). Additionally, we directly assessed the degree of US devaluation by measuring fear responding to the US. If an S-R association is created during acquisition trials, then the target cue (X) should retain some behavioral control even after complete US devaluation. To evaluate this possibility, a 2 (Pairing: Paired vs. Unpaired) $\times$ 2 (US Devaluation: US Devaluation vs. No US Devaluation) $\times$ 2 (Test Stimulus: X vs. US) between-subjects design was used (see Table 1). In order to minimize any associative strength accrued by the test context summing with that of the punctate test stimulus, testing was conducted in a context distinctively different from that of treatment.

Method

Subjects—Subjects were 48 male and 48 female, experimentally naive, Sprague-Dawley descended rats obtained from our own breeding colony. Body-weight ranges were 268–387 g for males and 200–275 g for females. Subjects were randomly assigned to one of eight groups ($n_s = 12$; Paired-USDev-X, Paired-USDev-US, Paired-NoUSDev-X, Paired-NoUSDev-US, Unpaired-USDev-X, Unpaired-USDev-US, Unpaired-NoUSDev-X, and Unpaired-NoUSDev-US), counterbalanced within groups for sex. The animals were individually housed in standard hanging stainless-steel wire-mesh cages in a vivarium maintained on a 16/8-hr light/dark cycle. Experimental manipulations occurred near the middle portion of the light phase. The animals received free access to Purina Lab Chow, while water availability was limited to 20 min per day following a progressive deprivation schedule initiated 1 week prior to the start of the study. From the time of weaning until the start of the study, all animals were handled for 30 s, three times per week.

Apparatus—Six identical copies each of two different types of experimental chambers were used. Chamber V was a 27-cm long box in a truncated-V shape (29.5-cm height, 21.5-cm wide at top, and 5.5-cm wide at bottom). The floor was comprised of two 27-cm long, 2-cm wide stainless plates, with a 1.5-cm gap between the two plates. The ceiling was clear Plexiglas, the front and back walls were black Plexiglas, and the sidewalls were stainless steel. Each of six copies of Chamber V was housed in a separate sound- and light-attenuating environmental isolation chest. The chamber was illuminated by a 7-W (nominal at 120 VAC, but driven at 50 VAC) light bulb, which was mounted on the inside wall of the environmental enclosure, approximately 30-cm from the center of the experimental

chamber. The light entered the chamber primarily by reflection from the ceiling of the environmental chest.

Chamber R was rectangular, measuring $24.0 \times 9.0 \times 12.5$ cm (length $\times$ width $\times$ height). The walls and ceiling of Chamber R were clear Plexiglas, and the floor was comprised of stainless steel rods measuring 0.5-cm diameter, spaced 1.3-cm apart (center to center). Each of six copies of Chamber R was housed in separate light- and sound-attenuating environmental isolation chambers. Each chamber was dimly illuminated by a 2-W (nominal at 120 VAC, but driven at 50 VAC) incandescent house light mounted on an inside wall of the environmental chest located approximately 30-cm from the animal enclosure.

All Chambers could be equipped with a water-filled lick tube that extended 1-cm into a cylindrical niche, which was 4.5 cm in diameter, left right centered, with its bottom 1.75-cm above the floor of the apparatus and 5.0 cm deep. There was a photobeam detector 1-cm in front of the lick tube that was broken whenever the subject licked the tube. Three 45- Ω speakers on the inside walls of the isolation chests could deliver a very loud train of clicks (6 Hz, 30 dB above background; a noise level that has been proved aversive in previous research—see, for example, Rescorla, 1973), a complex tone (450 and 550 Hz, 6 dB above background), or a white noise (6 dB above background). Ventilation fans in each enclosure provided a constant 76-dB background noise. All auditory cues were measured on the C-scale. The light intensities inside the two chambers were approximately equal due to the difference in opaqueness of the walls of Chambers V and R.

A 5-s tone served as CS X, a 5-s white noise served as CS Y, and a 5-s click served as the US. The physical identity of Contexts A and B were counterbalanced between Chambers R and V within groups.

Procedure

Acclimation: On Day 1, all subjects were acclimated to Context A in one 40-min session. Water tubes were absent on this acclimation day. On Days 2 and 3, all subjects were acclimated to Context B during a daily 40-min session. During these two acclimation days, subjects had free access to water-filled lick tubes. There were no presentations of the CS or US during this phase. At the end of acclimation, water tubes were removed until reacclimation.

Acquisition: On Day 4, subjects in the Paired condition received a 60-min conditioning training session in Context A. These subjects received two presentations of CS X followed immediately by the US (i.e., delay conditioning), and two presentations of CS Y alone with an average ITI of 15 min (from CS onset to CS onset). The nonreinforced trials (Y-) occurred 5 and 18 min into the session. The reinforced trials (X+) occurred 36 and 52 min into the session. Subjects in the Unpaired condition received a similar 60-min conditioning session but CS X was the nonreinforced cue and CS Y was reinforced instead.

US devaluation: On Days 5-8, subjects in the US Devaluation condition received one daily 60-min session in Context A. In each of these sessions subjects received six presentations of the US alone with an average ITI of 10 min (from CS onset to CS onset) at 5, 15, 30, 37, 45, and 56 min into the session. Subjects in the No US Devaluation condition received a daily 60-min session of exposure to Context A without any stimuli presentation.

Reacclimation: On Days 9-10, all subjects were reacclimated to Context B in daily 60-min sessions. Subjects had free access to the water-filled lick tubes and no nominal stimuli were programmed to occur. The purpose of these sessions was to reestablish a stable rate of drinking behavior (which might have been disrupted by the US), thereby providing similar

baseline drinking behavior across the four groups for which conditioned lick suppression was to be assessed.

Testing: On Day 11, all subjects were tested for conditioned lick suppression in Context B. Subjects in the X condition were tested for responding to CS X, while subjects in the US condition were tested for responding to the US. Upon placement in the test chamber, time spent drinking by each subject was recorded. Immediately after completion of an initial 5 cumulative seconds of licking in the absence of any nominal stimulus, subjects were presented with CS X or the US, depending on the experimental condition. Thus, all subjects were drinking at the time of the test stimulus onset. Time taken to complete an additional 5 cumulative seconds of licking in the presence of the test stimulus was recorded. The test session was 16 min in duration, and a ceiling score of 15 min was imposed on the time to complete five cumulative seconds of drinking in the presence of the testing cue.

Following the convention of our laboratory, all animals that took more than 60 s to complete their first 5 cumulative seconds of licking (i.e., prior to test stimulus onset) during the test session were scheduled to be eliminated from the study because such long latencies may be considered indicative of unusually great fear of the test context (which was distinctly different from the conditioning context). In practice, no subjects met this elimination criterion in any of the experiments in this series.

Data Analysis—For this and the following experiments, latencies to drink for 5 cumulative seconds before the onset of the test stimulus (pre-CS or pre-US in the present experiment) and after the onset of the test stimulus were transformed to $\log_{10}$ to better approximate the normal distributions assumed by parametric statistical analyses. To maintain consistency across experiments in this series, we used an analysis of variance (ANOVA) to determine whether our manipulations affected subjects' log latencies to drink in the presence of the test stimulus. The error term from the ANOVA served as an estimate of within-group variance in planned comparisons. Effect size was estimated using Cohen's f (Myers & Wells, 2003). Alpha was set at .05.

Results and Discussion

The results of Experiment 1 are depicted in Figure 1. As can be seen in the right panel of Figure 1, when US-alone presentations were administered (i.e., US devaluation), unconditioned fear to the US was abolished. In other words, subjects stopped suppressing their drinking behavior in the presence of the US after it was devalued, showing a complete devaluation of its unconditioned behavioral control (i.e., equal suppression to the US in Group Unpaired-USDev-US and to X in Group Unpaired-NoUSDev-X). Moreover, after the US devaluation treatment, Paired subjects (Groups Paired-USDev-X vs. Paired-NoUSDev-X) still suppressed their drinking behavior in the presence of CS X, even when the US itself stopped evoking fear responses. These results suggest that our preparation was successful in producing a complete devaluation of the US, and more importantly, that post-US devaluation, suppression to X in the Paired condition reflected a residual S-R association in first-order fear conditioning that was independent of the unconditioned behavioral control supported by the US. The following statistical analysis supported these conclusions.

A 2 (Pairing: Paired vs. Unpaired) $\times$ 2 (US Devaluation: US Devaluation vs. No US Devaluation) $\times$ 2 (Test Stimulus: X vs. US) ANOVA on the log pre-CS and log pre-US scores from the test session was conducted to determine if there were any between-group differences in fear to the test context prior to the onset of the test stimulus. Only the interaction between Pairing and Test Stimulus proved significant, $F(1, 88) = 5.18$, $MSE = 0.04$, Cohen's $f = 0.21$. None of the main effects or other interactions reached significance,

smallest $p = .13$. A planned comparison indicated that subjects of the Unpaired-X condition were more afraid of the test context than were subjects in the Paired-X condition, $F(1, 88) = 5.79$. Notably, this difference in baselines was in the opposite direction to the difference expected for these conditions during stimulus testing; thus, any effect of this difference on responding to the target CS should have reduced our expected differences.

A similar ANOVA was conducted on the log CS and log US scores. This analysis found a main effect of Pairing, $F(1, 88) = 17.87$, $MSE = 0.06$, Cohen's $f = 0.42$, US Devaluation, $F(1, 88) = 97.04$, Cohen's $f = 1.00$, Test Stimulus, $F(1, 88) = 7.37$, Cohen's $f = 0.26$, and interactions between Pairing and US Devaluation, $F(1, 88) = 6.07$, Cohen's $f = 0.23$, Pairing and Test Stimulus, $F(1, 88) = 21.20$, Cohen's $f = 0.46$, and between US Devaluation and Test Stimulus, $F(1, 88) = 106.51$, Cohen's $f = 1.05$. Planned comparisons were conducted to identify the sources of these effects.

Let us consider first the results found between groups in which the US was tested. The differences between Groups Paired-USDev-US and Paired-NoUSDev-US, and between Groups Unpaired-USDev-US and Unpaired-NoUSDev-US proved significant, $F(1, 88) = 119.59$, and $F(1, 88) = 85.29$, respectively, indicating that whether or not the US was paired with CS X, the unconditioned fear response to the US decreased when the US was devalued. Base level is indicated by suppression to CS X in the unpaired condition (Groups Unpaired-USDev-X and Unpaired-NoUSDev-X), as CS X should be innocuous given no pairing with the aversive click US. We see that suppression to the US following devaluation dropped to this baseline, suggesting that devaluation was complete.

When comparing groups in which CS X was tested, the difference between Groups Paired-NoUSDev-X and Unpaired-NoUSDev-X, and between Groups Paired-USDev-X and Unpaired-USDev-X proved significant, $F(1, 88) = 36.34$, and $F(1, 88) = 7.86$, respectively, indicating that the target CS acquired behavioral control when it was paired with the US. In a related comparison, no differences were found between Groups Paired-USDev-X and Paired-NoUSDev-X ($p = 0.17$), indicating that even after the US was completely devalued, the target CS retained a high level of behavioral control (i.e., a strong S-R association was evidenced).

These analyses suggest that essentially complete US devaluation occurred, and that our preparation encouraged S-R associations in first-order fear conditioning. Importantly, this S-R association is proposed as an animal model for phobias in which people do not remember conditioning events as causes of their fears. Subjects in the Group Paired-USDev-X were still afraid of the target CS (i.e., they still suppressed responding in the presence of CS X) even when the US itself stopped provoking fear responses.

Experiment 2: Extinction and Renewal of S-R Associations

Experiment 1 demonstrated the presence of an S-R association that was independent of a functional S-O association. In light of these results, Experiment 2 assessed the possibility of recovery of an extinguished S-R association when tested outside the extinction context (i.e., renewal). As mentioned previously, renewal is one of the phenomena that in the conditioning literature models relapse after exposure therapy and is commonly evidenced when extinguished associations are tested outside the context of extinction. However, whether fears without recall of causes (based on S-R associations) recover after extinction treatment remains unknown. To our knowledge, no effort to evaluate this possibility has been reported to date. To evaluate this possibility, a 2 (US Devaluation: US Devaluation vs. No US Devaluation) $\times$ 3 (Renewal: ABC vs. ABB vs. A-C) between-subjects design was used (see Table 2).

Method

Subjects—Subjects were 36 male and 36 female, experimentally naive, Sprague-Dawley descended rats obtained from our own breeding colony. Body-weight ranges were 263-389 g for males and 187-307 g for females. Subjects were randomly assigned to one of six groups ($n_s = 12$; ABC-USDev, ABB-USDev, A-C-USDev, ABC-NoUSDev, ABB-NoUSDev, and A-C-NoUSDev), counterbalanced within groups for sex. The maintenance and housing of subjects were the same as in Experiment 1.

Apparatus—In addition to the six copies of Chambers R and V used in Experiment 1, a third type of chamber was used in Experiment 2. Chamber Modified-R was Chamber R with five modifications: (1) a different instance of Chamber R, (2) a clear Plexiglas floor, (3) the house light was off, (4) a daily drop of banana concentrate odor cue was placed onto a small block of wood located inside the isolation chest, and (5) the lick tube was never presented in this context. The physical identity of Contexts B and C were counterbalanced between Chambers R and V within groups. Context A was the Modified-R chamber for all groups.

Procedure

Acclimation: On Day 1, all subjects were acclimated to Context A as in Experiment 1. On Days 2-3, all subjects were acclimated to Context B and C in daily 40-min sessions separated by about 6 h. During these latter two acclimation days, subjects had free access to water-filled lick tubes. There were no presentations of the CS or US during this phase. At the end of acclimation, water tubes were removed until reacclimation.

Acquisition: On Day 4, all subjects received a 30-min conditioning training session in Context A, which consisted of two presentations of CS X followed immediately by the US (i.e., delay conditioning) with a mean ITI of 15 min (from CS onset to CS onset). The reinforced trials occurred at 5 and 20 min into the session.

US devaluation: On Days 5-8, subjects in the US Devaluation condition received US devaluation training in Context A, exactly as in Experiment 1. Subjects in the No US Devaluation condition received equal exposure to Context A but without stimulus presentations.

Extinction: On Day 9, subjects in the ABC and ABB conditions received a 30-min extinction session in Context B. These subjects received 12 presentations of CS X alone initiated at 4.0, 8.0, 10.5, 13.0, 14.5, 15.0, 17.5, 20.0, 21.0, 24.0, 26.0 and 28.0 min into the session. The subjects received an equal amount of exposure to Context C. Subjects in the A-C condition received the same amount of exposure to Context B and C but no extinction of the target CS. Time between sessions within a day was approximately 5 h.

Reacclimation: On Days 10 and 11, all subjects were reacclimated receiving a daily 40-min session in Context B and another 40-min session in Context C. The rest of the procedure was identical to that of Experiment 1. Time between sessions within a day was approximately 6 h.

Testing and data analysis: On Day 12, all subjects were tested for conditioned lick suppression to CS X in Context B or C depending on the experimental condition. The rest of the testing procedure and data analysis were the same as in Experiment 1.

Results and Discussion

The results of Experiment 2 are depicted in Figure 2. As can be seen, a conditioned fear response to the CS X was evidenced when no extinction training took place (A-C condition). However, this responding was debilitated by extinction trials when testing occurred in the extinction context (ABB condition), and recovered when testing occurred in a neutral (but familiar) context (ABC condition). These results were not significantly affected by the US devaluation treatment. In other words, ABC renewal of the extinguished conditioned response was evidenced independent of whether or not the subjects received US devaluation treatment, a result that suggests that S-R associations (just like S-O and S-R associations together) are susceptible to recovery. In this case, recovery was caused by a shift of the physical context between extinction and testing (i.e., renewal). The following statistical analysis supported these conclusions.

A 2 (US Devaluation: US Devaluation vs. No US Devaluation) $\times$ 3 (Renewal: A-C vs. ABB vs. ABC) ANOVA on the log pre-CS scores from the test session was conducted to determine if there were any between-group differences in fear to the test contexts prior to the onset of the test stimulus. This analysis found no main effect of Renewal ($p = 0.53$) nor an interaction between US Devaluation and Renewal ($p = 0.84$) on baseline drinking, but the main effect of US Devaluation was marginally significant, $F(1, 66) = 3.63$, $MSE = 0.03$, Cohen's $f = 0.19$, $p < 0.07$. Most likely this difference in baseline, which approached significance, is a spurious finding and, more importantly, the difference is not one that could have contributed to any of the relevant differences observed in the CS scores.

A similar ANOVA was conducted on the log CS scores. This analysis found a main effect of Renewal, $F(2, 66) = 54.26$, $MSE = 0.05$, Cohen's $f = 1.05$, but not of US Devaluation, nor any interaction between these factors (smallest $p = 0.58$). Planned comparisons were conducted to identify the sources of this effect. In the No US Devaluation condition, the A-C group differed from the ABB group, $F(1, 66) = 58.20$, indicating that extinction treatment was effective in decreasing conditioned responses to the target CS. The ABB group also differed from the ABC group, $F(1, 66) = 20.66$, indicating that the extinguished conditioned responses were renewed in this condition (i.e., ABC renewal was found). Importantly, the same pattern of results was found when the US was devalued. In the US Devaluation condition, the A-C group differed from the ABB group, $F(1, 66) = 47.34$, indicating that extinction treatment was effective in decreasing conditioned responses to the target CS when only S-R associations were still in effect. The ABB group also differed from the ABC group, $F(1, 66) = 24.21$, indicating that the extinguished S-R association was also renewed (i.e., the extinguished S-R association was subject to ABC renewal). These analyses support the conclusion that ABC renewal of the extinguished conditioned responses occurred even when the US was devalued, a result that constitutes the first report of the renewal of an S-R association.

Experiment 3: Extinction and Spontaneous Recovery of S-R Associations

In Experiment 2, we found ABC renewal of the extinguished S-R association. To test the generality of the results of Experiment 2, the present experiment was designed to extend those results to a second recovery situation that models relapse after exposure therapy, spontaneous recovery. To evaluate the possibility of spontaneous recovery of S-R associations, we used a 2 (US Devaluation: US Devaluation vs. No US Devaluation) $\times$ 2 (Extinction: Extinction vs. No Extinction) $\times$ 3 (Delay: Immediate short vs. Immediate long vs. Delayed) between-subjects design (see Table 3). The Immediate Short (ImmShort) and Immediate Long (ImmLong) conditions represent two sets of control groups for spontaneous recovery. On one hand, Condition Immediate Short controls for the interval between acquisition and extinction but confounds the total interval between acquisition and testing.

On the other hand, Condition Immediate Long controls for the total interval between acquisition and testing but confounds the interval between acquisition and extinction. The two sets of control groups collectively permit a strict assessment of spontaneous recovery. Experiment 3's design differs from the previous experiments in three other ways. First, the US devaluation treatment occurred after the extinction phase (not before extinction treatment as in Experiment 2), thereby avoiding a decrement in the effectiveness of the repeated presentations of the US after a long delay (21 days) in our experimental condition (i.e., Condition Del). Second, the US devaluation treatment took place in half the number of sessions that was used in Experiments 1 and 2 (but keeping the same number of US presentations), in an effort to minimize spontaneous recovery from extinction in our control groups (i.e., Conditions ImmShort and ImmLong). And third, all phases of treatment occurred in only one context, thereby eliminating the possibility of context shift effects (i.e., renewal) explaining recovery in this experiment.

Method

Subjects—Subjects were 72 male and 72 female, experimentally naive, Sprague-Dawley descended rats obtained from our own breeding colony. Body-weight ranges were 264-409 g for males and 183-342 g for females. Subjects were randomly assigned to one of 12 groups ($n_s = 12$; ImmShort-NE-USDev, ImmShort-NE-NoUSDev, ImmShort-Ext-USDev, ImmShort-Ext-NoUSDev, ImmLong-NE-USDev, ImmLong-NE-NoUSDev, ImmLong-Ext-USDev, ImmLong-Ext-NoUSDev, Del-NE-USDev, Del-NE-NoUSDev, Del-Ext-USDev, and Del-Ext-NoUSDev, with Ext indicating Extinction, NE indicating No Extinction, and Del indicating Delay), counterbalanced within groups for sex. The maintenance and housing of subjects were the same as in Experiments 1 and 2.

Apparatus—Twelve identical copies of Chamber R were used in this experiment. All phases took place in the same context.

Procedure

Acclimation: On Days 1-2, all subjects were acclimated to the training context in a daily 30-min session. During these acclimation days, subjects had free access to water-filled lick tubes. There were no presentations of the CS or US during this phase. At the end of acclimation, water tubes were removed until reacclimation.

Acquisition: On Day 3, all subjects received a 30-min conditioning training session as in Experiment 2.

Extinction 1: On Day 4, subjects in the ImmShort-Ext-USDev, ImmShort-Ext-NoUSDev, Del-Ext-USDev, and Del-Ext-NoUSDev groups received a 30-min extinction session in the training context as in Experiment 2. Subjects in the groups ImmShort-NE-USDev, ImmShort-NE-NoUSDev, Del-NE-USDev, and Del-NE-NoUSDev groups received an equal amount of exposure to the training context, but no extinction of the target CS took place.

US devaluation 1: On Days 5-6, subjects in the ImmShort-NE-USdev and ImmShort-Ext-USdev groups received one daily 60-min session in the training context. During each of these sessions, subjects received 12 presentations of the US alone at 5, 9, 15, 19, 25, 30, 34, 38, 43, 47, 53 and 58 min into the session. Subjects in the ImmShort-NE-NoUSDev and ImmShort-Ext-NoUSDev groups received a daily 60-min session of exposure to the training context without any stimulus presentation.

Reacclimation 1: On Days 7-8, subjects in the ImmShort condition were reacclimated to the context during a daily 30-min session with the lick tubes present as in Experiments 1 and 2.

Test 1: On Day 9, subjects of the ImmShort condition were tested for conditioned lick suppression to CS X in the training context as in Experiments 1 and 2.

Retention Interval 1: On Days 4-24, subjects of the ImmLong condition stayed in their home cages. Subjects were handled for 30 s, three times per week during this period.

Retention Interval 2: On Days 5-25, subjects of the Del condition stayed in their home cages. Subjects were handled for 30 s, three times per week during this period.

Extinction 2: On Day 25, subjects in the ImmLong-Ext-USDev and ImmLong-Ext-NoUSDev groups received a 30-min extinction session in the training context identical to the procedure of Extinction 1 in this experiment. Subjects in the ImmLong-NE-USDev and ImmLong-NE-NoUSDev groups received an equal amount of exposure to the training context, but no extinction of the target CS took place.

US devaluation 2: On Days 26-27, subjects in the ImmLong-NE-USDev, ImmLong-Ext-USDev, Del-NE-USDev, and Del-Ext-USDev groups received one daily 60-min US devaluation session in the training context identical to the procedure of US Devaluation 1 in this experiment. Subjects in the ImmLong-NE-NoUSDev, ImmLong-Ext-NoUSDev, Del-NE-NoUSDev, and Del-Ext-NoUSDev groups received a daily 60-min session of exposure to the training context without any stimuli presentation.

Reacclimation 2: On Days 28-29, subjects in the ImmLong and Del conditions were reacclimated identically to the procedure of Reacclimation 1 in this experiment.

Test 2: On Day 30, subjects of the ImmLong and Del conditions were tested for conditioned lick suppression to CS X in the training context, as in Test 1 of this experiment.

Data Analysis: The data of the two sets of control groups were contrasted using a 2 (Delay: Immediate short vs. Immediate long) $\times$ 2 (US Devaluation: US Devaluation vs. No US Devaluation) $\times$ 2 (Extinction: Extinction vs. No Extinction) ANOVA. No difference between these conditions was found in any of the possible main effects or interactions (smallest $p = 0.12$). Because the ImmShort and ImmLong conditions did not differ, they were collapsed into one condition referred to as Immediate. The rest of the data analysis was exactly as in Experiments 1 and 2.

Results and Discussion

The results of Experiment 3 are depicted in Figure 3. As can be seen, appreciable fear to CS X was evidenced when no extinction treatment took place (No Extinction condition), independent of whether or not the subjects received US devaluation. However, the level of responding was lower for the No Extinction groups in which US devaluation took place. Based on the results of the prior two studies, this difference in suppression was expected because conditioned suppression in groups that did not receive US devaluation should reflect summation of S-R and S-O associations, but in the groups that did receive US devaluation, conditioned suppression should reflect only S-R associations. Conditioned responding was diminished by extinction trials when testing occurred immediately after extinction, but not when a long delay was imposed between extinction trials and testing (i.e., spontaneous recovery was evidenced). Notably, these results were not appreciably affected by the US devaluation treatment. In other words, spontaneous recovery of the extinguished conditioned responses was evidenced whether or not the subjects received US devaluation treatment, a result that suggests that recovery of extinguished S-R associations (just like S-O and S-R associations together) is facilitated not only by a shift in the physical context (i.e.,

renewal; see Experiment 2) but also by a long delay between extinction and testing (i.e., spontaneous recovery). The following statistical analysis supported these conclusions.

A 2 (US Devaluation: US Devaluation vs. No US Devaluation) $\times$ 2 (Extinction: Extinction vs. No Extinction) $\times$ 2 (Delay: Immediate vs. Delayed) ANOVA on the log pre-CS scores from the test session found no main effects or interactions in baseline drinking (smallest $p = 0.24$).

A similar ANOVA was conducted on the log CS scores. This analysis found a main effect of Extinction, $F(1, 136) = 91.91$, $MSE = 0.06$, Cohen's $f = 0.80$; US Devaluation, $F(1, 136) = 43.74$, Cohen's $f = 0.55$; Delay, $F(1, 136) = 61.51$, Cohen's $f = 0.65$; and interactions between Extinction and US Devaluation, $F(1, 136) = 12.11$, Cohen's $f = 0.28$; Extinction and Delay, $F(1, 136) = 28.39$, Cohen's $f = 0.44$; and between US Devaluation and Delay, $F(1, 136) = 7.32$, Cohen's $f = 0.21$, but not US Devaluation, Delay, and Extinction, $p = 0.56$.

Planned comparisons were conducted to identify the sources of these effects. Let us consider first the results in the No Extinction condition. The differences between Groups Imm-NE-USDev and Imm-NE-NoUSDev, and between Del-NE-USDev and Del-NE-NoUSDev proved significant, $F(1, 136) = 23.86$, and $F(1, 136) = 27.95$, respectively, indicating that in the present experiment the S-R associations (i.e., responding to the CS X when the US was devalued) were weaker than the S-O and S-R associations together (i.e., responding to the CS X when the US was not devalued). In addition, responding to CS X did not differ between Groups Imm-NE-USDev and Del-NE-USDev, $p = 0.84$, indicating that when the US was devalued, a delay did not influence the behavior control by CS X. However, a difference was found when comparing Groups Imm-NE-NoUSDev and Del-NE-NoUSDev, $F(1, 136) = 5.36$, suggesting that the delay increased (i.e., incubated) responding when no extinction had taken place, but only when the S-O association had not been diminished through US devaluation procedures.

In the Immediate condition, differences were found depending on whether or not the subjects had received extinction trials. In other words, the differences between Groups Imm-NE-USDev and Imm-Ext-USDev, and between Groups Imm-NE-NoUSDev and Imm-Ext-NoUSDev proved significant, $F(1, 136) = 44.13$, and $F(1, 136) = 135.12$, respectively, indicating that the extinction treatment effectively decreased behavioral control of the CS X.

Consider now the Extinction condition. A difference was found between the Imm-Ext-NoUSDev and Del-Ext-NoUSDev groups, $F(1, 136) = 67.76$, indicating that the extinguished conditioned responses recovered when a delay between extinction and testing was imposed (i.e., spontaneous recovery of the extinguished S-O and S-R associations together). Importantly, the same effects were observed when the US was devalued. Differences were found between the Imm-Ext-USDev and Del-Ext-USDev groups, $F(1, 136) = 24.40$, suggesting that when only S-R associations supported responding to CS X, the extinguished conditioned responses recovered when a delay was imposed (i.e., spontaneous recovery of the extinguished S-R association).

These analyses support the conclusion that spontaneous recovery of extinguished conditioned fear responses occurs whether or not the US has been devalued, a result that constitutes the first report of spontaneous recovery of an S-R association.

General Discussion

In three lick suppression experiments with rats as experimental subjects, we evaluated the possibility of S-R associations in first-order fear conditioning as an associative account for fears and phobias for which patients do not remember a conditioning event as the cause of

their fears, and the possibility of relapse after successful extinction of those S-R associations. More specifically, in Experiment 1 the possibility of S-R association in first-order fear conditioning was evaluated using US devaluation procedure similar to the one used by Rescorla (1973). In contrast with Rescorla's experiment (Rescorla, 1973; Exp 3), Experiment 1 of this series directly assessed the degree of US devaluation to assure that the effect of the procedure was complete and that the US was no longer capable of provoking an unconditioned fear response. This minimized the possibility of an S-O contribution to responding to the target CS. Consistent with an S-R association being formed during acquisition trials, the target CS retained behavioral control even after complete US devaluation. Simply stated, after US devaluation our experimental subjects stopped being afraid of the loud clicks (US), but continued suppressing their drinking behavior when the tone was tested (i.e., the CS still evoked fear).

These results corroborate Rescorla's results (1973) in a more controlled experiment, and provide evidence of S-R associations in first-order fear conditioning, suggesting that S-R associations (and not just S-R associations created by second-order conditioning as previously proposed; Dollard & Miller, 1950; Mineka, 1985; Rizley & Rescorla, 1972) can account for fears and phobias without recall of causes (i.e., conditioning events). In other words, Experiment 1's results could explain, within an associative framework, why many individuals do not remember a traumatic conditioned event precipitating their phobias. This new associative account, added to the associative accounts proposed by Esteves et al. (1994), Davey (1992), Cook and Mineka (1987), and Field (2006), leave no doubts that within the conditioning tradition there are possible explanations for these types of fears, and the lack of such an explanation should be removed from the list of shortcomings of this approach (Fyer, 1998).

In Experiments 2 and 3, the possibility of a recovery of extinguished S-R associations was examined. Experiment 2 evaluated the recovery of an extinguished S-R association in an ABC renewal design. Fear responding to the extinguished CS was renewed when testing occurred in an associatively neutral context, an effect that was little diminished by US devaluation treatment. In other words, ABC renewal of the extinguished CR was evidenced with and without devaluation of the S-O link between the CS and the US. A shift of the physical context between extinction and testing provoked a reappearance of the extinguished S-O and S-R associations together (Bouton & Bolles, 1979) but also renewed the extinguished S-R association alone.

Experiment 3 extended Experiment 2's results to a second recovery situation, spontaneous recovery. In this experiment, two different conservative control conditions were used to assess the effect of a delay between the extinction trials and testing on the return of fear to the CS. One set of control groups was used to control for the interval between acquisition and extinction (ImmShort condition) and another to control for the interval between acquisition and testing (ImmLong condition). No difference was found between these controls. Conditioned fear to the extinguished CS was recovered when a delay between extinction trials and testing was imposed, with little effect of the US devaluation treatment. In other words, spontaneous recovery of the extinguished CR was evidenced with and without blocking the S-O link between the CS and the US. Twenty-one days between extinction treatment and testing provoked a reappearance of the extinguished S-O and S-R associations together and also recovered the extinguished S-R association alone. To our knowledge, this is the first report of renewal and spontaneous recovery of extinguished S-R associations.

These results add to the numerous reports of recovery from extinction in the nonhuman animal literature (e.g., Bouton & Bolles, 1979; Bouton & King, 1983; Bouton & Ricker,

1994; Brooks & Bouton, 1993; Pavlov, 1927; Robbins, 1990). Of importance, similar results have been found in the human conditioning literature and in preclinical research (for a review, see Laborda, McConnell, & Miller, in press). For instance, using a contingency learning task, Vila and Rosas (2001) found renewal and spontaneous recovery in a nonclinical human sample. In their study, an association between a medicine (CS) and an injurious effect (US) was formed (presenting the CS and US contiguously) and then extinguished (presenting the CS in the absence of the US). After these treatments, the extinguished association was recovered when testing occurred outside the extinction context (i.e., renewal) or after a long delay (i.e., spontaneous recovery). Also within human conditioning, Vansteenwegen et al. (2005) evidenced renewal in a fear conditioning preparation. In the critical experimental group, a picture (CS) and a loud aversive sound (US) were associated in one context and extinguished in a different context. When the CS was tested back in the acquisition context, the extinguished fear response was recovered compared with a group in which all phases (acquisition, extinction, and testing) occurred at the same context. As mentioned above, these recovery from extinction phenomena also have parallels in the preclinical literature. For example, Collins and Brandon (2002) reported a recovery of extinguished reactivity of the urge to drink and extinguished salivatory responses. In their study, social drinkers received extinction of alcohol-related cues. Social drinkers who were tested for salivation and urge-to-drink responses in the context in which extinction took place showed low levels of these responses (i.e., extinction). However, participants tested outside the extinction context showed a recovery of them. Also using a preclinical sample, Mystkowski, Craske, and Echiverri (2002) observed recovery of extinguished fear responses in spider-fearful participants. Participants of this study received exposure therapy for their fear to spiders and then were tested a few days later in the treatment context or in a new context. Those participants tested in a different context showed a recovery of the extinguished fear responses compared with the group tested in the treatment context.

As is evident to this point, recovery from extinction phenomena are widely reported in the animal and human literature and they represent models of relapse after exposure therapy. Of importance, a number of behavioral techniques to reduce recovery from extinction have proven to be successful in the experimental laboratory and likely they would prove effective if implemented to prevent relapse after exposure therapy as well (for a detailed review, see Laborda et al., in press). For instance, Denniston, Chang, and Miller (2003; see also Laborda & Miller, 2010) reported that massive extinction treatment reduced renewal in a series of experiments in a fear-conditioned preparation with rats as experimental subjects. The group that received a massive amount of extinction training (800 trials) showed less recovery from extinction after a context shift (i.e., renewal) than a group that received only a moderate amount of extinction trials (160). Denniston et al.'s results have a parallel in the prolonged exposure therapy proposed by Powers, Halpern, Ferenschak, Gillihan, and Foa (2010) to treat patients with posttraumatic stress disorders. Another technique to reduce recovery from extinction has been presented by Urcelay, Wheeler, and Miller (2009; see also Laborda, Miguez, & Miller, 2010). In their research, also using a fear-conditioned preparation with rats, spacing extinction trials reduced renewal and spontaneous recovery compared with a group in which the extinction trials were massed. A related finding was reported by Tsao and Craske (2000) when spacing exposure sessions in spider-fearful participants. Whether the same procedures that reduce recovery from extinction when S-O associations are intact apply when only S-R associations are in effect is an open question, but we see no principled reason to think they would be less effective in that situation.

The present results support the view that fears and phobias without recall of the original conditioning event can be explained at an associative level. Importantly, the account proposed does not rely on one specific preparation (i.e., second-order fear conditioning, as

proposed by Dollard & Miller, 1950; Mineka, 1985; Rizley & Rescorla, 1972), but on a general type of S-R association that can be involved in first-order conditioning. S-R associations serve as a plausible account for these kinds of phobias and provide an empirical associative account of conditioned fear and phobias existing without recall of the precipitating incident because the conditioning event is not part of the associative structure. Lamentably, Experiments 2 and 3 suggest that these phobias without recall of causes are susceptible to relapse just like phobias in which patients remember the cause of their fear. In summary, to the extent that S-R associations underlie anxiety disorders when the precipitating conditioning event is not recalled, exposure therapy should be as effective as when the conditioning event is recalled. Unfortunately, decreased anxiety in this case is as susceptible to relapse as when the conditioning event can be recalled.

Acknowledgments

National Institute of Mental Health Grant 33881 supported this research. The authors thank Joseph Alessandro, Meredith Coles, Eric Curtis, Bridget McConnell, Gonzalo Miguez, Cody Polack, Sarah Sterling, Yumu Tanaka, Deanne Westerman, and James Witnauer for their comments on an earlier version of this manuscript. Special thanks to Andy Field for his valuable comments. Mario Laborda was supported by the Comisión Nacional de Investigación Científica y Tecnológica (CONICYT-Chile) and the Department of Psychology of the Universidad de Chile.

References

- American Psychiatric Association. Diagnostic and statistical manual of mental disorders. 4th ed.. Author; Washington, DC: 1994.
- Alonso J, Angermeyer MC, Bernert S, Bruffaerts R, Brugha TS, Bryson H, et al. Prevalence of mental disorders in Europe: Results from the European study of the epidemiology of mental disorders (ESEMeD) project. *Acta Psychiatrica Scandinavica*. 2004; 109:21–27. [PubMed: 15128384]
- Becker ES, Rinck M, Turke V, Kause P, Goowin R, Neumer S, et al. Epidemiology of specific phobia subtypes: Findings from the Dresden mental health study. *European Psychiatry*. 2007; 22:69–74. [PubMed: 17157482]
- Bouton ME. Context, time, and memory retrieval in the interference paradigm of pavlovian learning. *Psychological Bulletin*. 1993; 114:80–99. [PubMed: 8346330]
- Bouton ME. A learning theory perspective on lapse, relapse, and the maintenance of behavior change. *Health Psychology*. 2000; 19:57–63. [PubMed: 10709948]
- Bouton ME. Context, ambiguity, and unlearning: Sources of relapse after behavioral extinction. *Biological Psychiatry*. 2002; 52:976–986. [PubMed: 12437938]
- Bouton ME. Context and behavioral processes in extinction. *Learning & Memory*. 2004; 11:485–494. [PubMed: 15466298]
- Bouton ME, Bolles RC. Contextual control of the extinction of conditioned fear. *Learning and Motivation*. 1979; 10:445–466.
- Bouton ME, King DA. Contextual control of the extinction of conditioned fear: Tests for the associative value of the context. *Journal of Experimental Psychology: Animal Behavior Processes*. 1983; 9:248–265. [PubMed: 6886630]
- Bouton, ME.; Nelson, JB. The role of context in classical conditioning: Some implications for cognitive behavior therapy. In: O'Donohue, W., editor. *Learning and behavior therapy*. Allyn and Bacon; Boston: 1998. p. 59–84.
- Bouton ME, Ricker ST. Renewal of extinguished responding in a second context. *Animal Learning & Behavior*. 1994; 22:317–324.
- Brooks DC, Bouton ME. A retrieval cue for extinction attenuates spontaneous recovery. *Journal of Experimental Psychology: Animal Behavior Processes*. 1993; 19:77–89. [PubMed: 8418218]
- Chambless DL, Sanderson WC, Shoham V, Bennett Johnson S, Pope KS, Crits-Christoph P, et al. An update on empirically validated therapies. *Clinical Psychologist*. 1996; 49:5–18.

- Chambless DL, Ollendick T. Empirically supported psychological interventions: Controversies and evidence. *Annual Review of Psychology*. 2001; 52:685–716.
- Collins BN, Brandon TH. Effects of extinction context and retrieval cues on alcohol cue reactivity among nonalcoholic drinkers. *Journal of Consulting and Clinical Psychology*. 2002; 70:390–397. [PubMed: 11952197]
- Cook M, Mineka S. Second-order conditioning and overshadowing in the observational conditioning of snake fear in monkeys. *Behaviour Research and Therapy*. 1987; 25:349–364. [PubMed: 3689293]
- Craske, M. *Anxiety disorders: Psychological approaches to theory and treatment*. Westview Press; Boulder: 1999.
- Davey GCL. Classical conditioning and the acquisition of human fears and phobias: A review and synthesis of the literature. *Advances in Behaviour Research and Therapy*. 1992; 14:29–66.
- Davey GCL, de Jong PJ, Tallis F. UCS inflation in the etiology of a variety of anxiety disorders: Some case histories. *Behaviour Research and Therapy*. 1993; 31:495–498. [PubMed: 8333824]
- Denniston JC, Chang RC, Miller RR. Massive extinction attenuates the renewal effect. *Learning and Motivation*. 2003; 34:68–86.
- Dollard, J.; Miller, NE. *Personality and psychotherapy: An analysis in terms of learning, thinking, and culture*. McGraw-Hill; New York: 1950.
- Dwyer DM. Learning about cues in their absence: Evidence from flavour preferences and aversions. *Quarterly Journal of Experimental Psychology*. 2003; 56B:56–67. [PubMed: 12623537]
- Esteves F, Dimberg V, Öhman A. Automatically elicited fear: Conditioned skin conductance response to masked facial stimuli. *Cognition and Emotion*. 1994; 8:393–413.
- Field AP. Is conditioning a useful framework for understanding the development and treatment of phobias? *Clinical Psychology Review*. 2006; 26:857–875. [PubMed: 16472895]
- Fyer AJ. Current approaches to etiology and pathophysiology of specific phobia. *Biological Psychiatry*. 1998; 44:1295–1304. [PubMed: 9861472]
- Kazdin, AE. Experimental neurosis. In: Kazdin, AE., editor. *Encyclopedia of psychology*. Vol. 3. Oxford University Press; New York: 2000. p. 297-298.
- Laborda, MA.; McConnell, BL.; Miller, RR. Behavioral techniques to reduce relapse after exposure therapy: Applications of studies of experimental extinction. In: Schachtman, T.; Reilly, S., editors. *Applications of conditioning theory*. Oxford University Press; New York: in press
- Laborda MA, Miller RR. Preventing recovery from extinction in an animal model of anxiety: I. Additive effect of massive extinction and extinction in multiple contexts. 2010 Manuscript submitted for publication.
- Laborda MA, Miguez G, Miller RR. Preventing recovery from extinction in an animal model of anxiety: II. Additive effect of spacing extinction trials and sessions. 2010 Manuscript submitted for publication.
- McNally RJ, Steketee GS. The etiology and maintenance of severe animal phobias. *Behavior Research and Therapy*. 1985; 23:431–435.
- Menzies RG, Clarke JC. The etiology of fear of heights and its relationship to severity and individual response patterns. *Behavior Research and Therapy*. 1993; 31:355–365.
- Merckelbach H, de Jong PJ, Muris P, van den Hout MA. The etiology of specific phobias: A review. *Clinical Psychology Review*. 1996; 16:337–361.
- Mineka, S. Animal models of anxiety-based disorders: Their usefulness and limitations. In: Tuma, AH.; Maser, JD., editors. *Anxiety and the anxiety disorders*. Erlbaum; Hillsdale, NJ: 1985. p. 199-244.
- Mineka S, Oehlberg K. The relevance of recent developments in classical conditioning to understanding the etiology and maintenance of anxiety disorders. *Acta Psychologica*. 2008; 127:567–580. [PubMed: 18226795]
- Mineka, S.; Sutton, J. Contemporary learning theory perspective on the etiology of fears and phobias. In: Craske, MG.; Hermans, D.; Vansteenwegen, D., editors. *Fear and learning: From basic processes to clinical implications*. American Psychological Association; Washington, DC: 2006. p. 75-97.

- Mineka S, Zinbarg R. A contemporary learning theory perspective on anxiety disorders: It's not what you thought it was. *American Psychologist*. 2006; 61:10–26. [PubMed: 16435973]
- Murray EJ, Foote F. The origins of fear of snakes. *Behavior Research and Therapy*. 1979; 17:489–493.
- Myers, JM.; Wells, AD. Research design and statistical analysis. 2nd ed.. Erlbaum; Mahwah, NJ: 2003.
- Mystkowski JL, Craske MG, Echiverri AM. Treatment context and return of fear in spider phobia. *Behavior Therapy*. 2002; 33:399–416.
- Öhman A, Mineka S. Fears, phobias, and preparedness: Toward an evolved module of fear and fear learning. *Psychological Review*. 2001; 108:483–522. [PubMed: 11488376]
- Olsson A, Phelps EA. Learned fear of “unseen” faces after Pavlovian, observational, and instructed fear. *Psychological Science*. 2004; 15:822–828. [PubMed: 15563327]
- Ost L, Hugdahl K. Acquisition of phobias and anxiety response patterns in clinical patients. *Behavior Research and Therapy*. 1981; 19:439–447.
- Ost L, Hugdahl K. Acquisition of agoraphobia, mode of onset and anxiety response patterns. *Behavior Research and Therapy*. 1983; 21:623–631.
- Pavlov, IP. Conditioned reflexes. Anrep, GV., editor. Oxford University Press; London: 1927. Trans.
- Poulton R, Menzies RG. Non-associative fear acquisition: A review of the evidence from retrospective and longitudinal research. *Behaviour Research and Therapy*. 2002; 40:127–149. [PubMed: 11814178]
- Powers MB, Halpern JM, Ferenschak MP, Gillihan SJ, Foa EB. A meta-analytic review of prolonged exposure for posttraumatic stress disorder. *Clinical Psychology Review*. 2010 doi: 10.1016/j.cpr.2010.04.007.
- Rachman S. The conditioning theory of fear-acquisition: A critical examination. *Behaviour Research and Therapy*. 1977; 15:375–387. [PubMed: 612338]
- Rescorla RA. The effect of US habituation following conditioning. *Journal of Comparative and Physiological Psychology*. 1973; 82:137–143. [PubMed: 4684968]
- Rescorla RA. Effect of inflation of the unconditioned stimulus value following conditioning. *Journal of Comparative and Physiological Psychology*. 1974; 86:101–106.
- Rimm DC, Janda LH, Lancaster DW, Nahl M, Dittmar K. An exploratory investigation of the origin and maintenance of phobias. *Behavior Research and Therapy*. 1977; 15:231–238.
- Rizley RC, Rescorla RA. Associations in second-order conditioning and sensory preconditioning. *Journal of Comparative and Physiological Psychology*. 1972; 81:1–11. [PubMed: 4672573]
- Robbins SJ. Mechanisms underlying spontaneous recovery in autoshaping. *Journal of Experimental Psychology: Animal Behavior Processes*. 1990; 16:235–249.
- Seligman ME. Phobias and preparedness. *Behavior Therapy*. 1971; 2:307–320.
- Somers JM, Goldner EM, Waraich P, Hsu L. Prevalence and incidence studies of anxiety disorders: A systematic review of the literature. *Canadian Journal of Psychiatry*. 2006; 51:100–113.
- Stinson FS, Dawson DA, Chou SP, Smith S, Goldstein RB, Ruan WJ, et al. The epidemiology of DSM-IV specific phobia in the USA: Results from the national epidemiologic survey on alcohol and related conditions. *Psychological Medicine*. 2007; 37:1047–1059. [PubMed: 17335637]
- Tsao JCI, Craske MG. Timing of treatment and return of fear: Effects of massed, uniform-, and expanding-spaced exposure schedules. *Behavior Therapy*. 2000; 31:479–497.
- Urcelay GP, Wheeler DS, Miller RR. Spacing extinction trials alleviates renewal and spontaneous recovery. *Learning & Behavior*. 2009; 37:60–73. [PubMed: 19122053]
- Vansteenwegen D, Hermans D, Vervliet B, Francken G, Beckers T, Baeyens F, et al. Return of fear in a human differential conditioning paradigm caused by a return to the original acquisition context. *Behaviour Research and Therapy*. 2005; 43:323–336. [PubMed: 15680929]
- Vila NJ, Rosas JM. Renewal and spontaneous recovery after extinction in a causal-learning task. *Mexican Journal of Behavior Analysis*. 2001; 27:79–96.
- Watson JB, Rayner R. Conditioned emotional reactions. *Journal of Experimental Psychology*. 1920; 3:1–14.
- Wolpe, J. Psychotherapy by reciprocal inhibition. Stanford University Press; Stanford, CA: 1958.

Wolpe J, Plaud JJ. Pavlov's contributions to behavior therapy: The obvious and the not so obvious. *American Psychologist*. 1997; 52:966–972. [PubMed: 9382243]

Figure 1.

Mean log time to complete 5 cumulative seconds of licking in the presence of test stimulus (CS X or US). See Table 1 for treatments. Brackets represent standard error of the mean. Higher scores indicate more conditioned suppression. As we measured time to completed 5 cumulative seconds of drinking, the minimum score possible was 0.7 log s.

Figure 2.

Mean log time to complete 5 cumulative seconds of licking in the presence of test stimulus (CS X) in Context B for the ABB group and in Context C for the ABC, and A-C groups. See Table 2 for treatments. Brackets represent standard error of the mean. Higher scores indicate more conditioned suppression. As we measured time to completed 5 cumulative seconds of drinking, the minimum score possible was 0.7 log s.

Figure 3.

Mean log time to complete 5 cumulative seconds of licking in the presence of test stimulus (CS X). See Table 3 for treatments. The ImmShort and ImmLong conditions were collapsed due to the lack of any difference between these control conditions. The Immediate condition represents then the collapsed data of ImmShort and ImmLong conditions. Brackets represent standard error of the mean. Higher scores indicate more conditioned suppression. As we measured time to completed 5 cumulative seconds of drinking, the minimum score possible was 0.7 log s.

Table 1

Design Summary of Experiment 1

Groups	Phase 1 Acquisition Context A	Phase 2 US Devaluation Context A	Test Context B
Paired-USDev-X	2 X-US / 2 Y	24 US	X
Paired-USDev-US			US
Paired-NoUSDev-X		-	X
Paired-NoUSDev-US			US
Unpaired-USDev-X	2 Y-US / 2 X	24 US	X
Unpaired-USDev-US			US
Unpaired-NoUSDev-X		-	X
Unpaired-NoUSDev-US			US

Note. CS X was a tone, and CS Y was a white noise (both 6 dB above background). “US” denotes reinforcement with a click train (30 dB above background). Numbers preceding X, Y, and “+” indicate total number of X, Y and US trials, respectively, in that phase. “-” indicates no treatment.

Table 2

Design Summary of Experiment 2

Groups	Phase 1 Acquisition	Phase 2 US Devaluation	Phase 3 Extinction	Test
ABC-USDev	(2 X-US) _A	(24 US) _A	(12 X) _B / (-) _C	(X) _C
ABB-USDev				(X) _B
A-C-USDev			(-) _B / (-) _C	(X) _C
ABC-NoUSDev		(-) _A	(12 X) _B / (-) _C	(X) _C
ABB-NoUSDev				(X) _B
A-C-NoUSDev			(-) _B / (-) _C	(X) _C

Note. CS X was a tone (6 dB above background). “US” denotes reinforcement with a click train (30 dB above background). A, B, and C were different contexts. Numbers preceding the letter X and “US” indicate total number of X trials and US trials in that phase. “-” indicates no treatment.

Table 3

Design Summary of Experiment 3

Groups	Phase 1 Acquisition Day 3	Phase 2a Extinction 1 Day 4	Phase 3a US Devaluation 1 Days 5-6	Test 1 Day 9	Retention Interval 1 Days 4-24	Phase 2b Extinction 2 Day 25	Retention Interval 2 Days 5-25	Phase 3 US Devaluation 2 Day 26-27	Test 2 Day 30
ImmShort-NE-USDev	2 X-US	Context	24 US	X	21 days	Context		24 US	X
ImmShort-NE-NoUSDev			Context	X					
ImmShort-Ext-USDev		12 X	24 US	X					
ImmShort-Ext-NoUSDev			Context	X					
ImmLong-NE-USDev									
ImmLong-NE-NoUSDev								Context	X
ImmLong-Ext-USDev						12 X		24 US	X
ImmLong-Ext-NoUSDev								Context	X
Del-NE-USDev		Context			21 days			24 US	X
Del-NE-NoUSDev								Context	X
Del-Ext-USDev		12 X						24 US	X
Del-Ext-NoUSDev								Context	X

Note. CS X was tone (6 dB above background). “+” denotes reinforcement with a click train (30 dB above background). Numbers preceding the letter X and “US” indicate total number of X trials and US trials in that phase. All treatments and testing occurred in the same context. “Context” indicates exposure to the context without treatment. Imm denotes Immediate, Del denotes Delay, Ext denotes Extinction, and NE denotes No Extinction.