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Role of context similarity in ABA, ABC, and AAB renewal paradigms: Implications for theories of renewal and for treating human phobias☆

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Abstract

Using barpress conditioned suppression, we studied the renewal of conditioned fear in rats, an animal model for the relapse of human fears and phobias. We demonstrated ABA renewal when the only differences between Contexts A and B included (1) their odor, (2) their location (i.e., side of room), and (3) unintended differences between copies of the same box at the two sites. Removing either the odor or location cues abolished the renewal effect. We then directly compared the effects of ABA and AAB procedures under two levels of context similarity. Although AAB renewal occurred, ABA renewal was stronger. Adding multiple context distinctions to the three listed above did not significantly enhance either form of renewal. Finally, we directly compared the strengths of AAB, ABC, and ABA renewal. AAB renewal, though again significant, was weaker than ABA and ABC renewal, which did not differ significantly. Fear renewal (relapse) can thus be reduced by extinguishing the fear in the acquisition context, regardless of the nature of the test context.

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Beginning with its discovery in laboratory rats, the phenomenon of fear renewal following fear extinction was recognized as a model of the relapse of human fears and phobias (Bouton & Bolles, 1979). In the typical renewal paradigm, a fear is established in one conditioning chamber, Context A, is extinguished in a distinctly different chamber, Context B, and is then assessed in the original context or in a new context, Context C. In either assessment, it is found to be much stronger than it was at the end of extinction (Bouton & Bolles, 1979; Bouton & King, 1983). In clinical practice, the B context usually corresponds to the therapist's office.

Recently, researchers using laboratory rats have begun to seek treatments that thwart the renewal of conditioned fear. Gunther, Denniston, and Miller (1998), found, for example, that ABC renewal could be greatly reduced by extinguishing the fear in several contexts before assessing it in one that had not been associated with either acquisition or extinction. (For work of similar import in conditioned taste aversion, see Chelonis, Calton, Hart, & Schachtman, 1999). Denniston, Chang, and Miller (2003) found that both ABC and ABA renewal could be attenuated by "massive" extinction exposure. Rauhut, Thomas, and Ayres (2001) found that ABA renewal could be abolished by several treatments in Context B, including Pavlov's (1960) conditioned inhibition treatment, a differential conditioning treatment, and an explicitly unpaired treatment. All of these treatments involved nonreinforced exposures to the feared conditioned stimulus (CS) intermingled with noncontiguous deliveries of the (shock) unconditioned stimulus (US) that was used originally to condition fear to the CS in Context A.

Experimentalists who have studied fear renewal have striven to make their A and B contexts differ as much as possible. For example, in an ABA renewal paradigm, Bouton and King (1983) used A and B contexts that differed in their internal dimensions, their construction materials, the diameter and spacing of floor grids, whether those grids were parallel to or perpendicular to a response bar, the size, shape, and location of that bar, and the proximity of the bar to the food cup. The food cups protruded into one context but not the other, and they dispensed different brands of food pellets. Moreover, the contexts were housed in different rooms, were differently scented, and access to them was provided through a lid in one case and through a side-opening door in the other.

Recent work from our own laboratory (Rauhut et al., 2001) used similarly elaborate distinctions between Contexts A and B and, additionally, associated each context with a unique device used to carry the rats from the colony to the experimental contexts.

Our initial aim in the present research was to ask whether such elaborate differences between A and B contexts are necessary to demonstrate ABA renewal. In Experiment 1a, we used eight similar operant boxes housed in a single, small

room. Boxes 1–4, always abutting the room's north wall, which served as Context A, and Boxes 5–8, always abutting the south wall, which served as Context B (counterbalanced). In Experiment 1a but not Experiment 1b, the contexts were also scented differently. All rats were transported identically to their experimental contexts. Renewal displayed under such conditions would have methodological, clinical, and heuristic implications. Methodologically, it would simplify matters for workers seeking to study renewal. Clinically, it would suggest that even modest differences between extinction and acquisition or extinction and test contexts might produce relapse. Heuristically, it would raise the question: just how similar can Context B get to Context A before the ABA renewal paradigm becomes an AAA paradigm, a paradigm known to prevent renewal (Bouton & Bolles, 1979; Bouton & King, 1983)? We address this question in Experiments 1b and 2. The answer leads to a further question: as B becomes so similar to A that renewal is thwarted, does the similarity of the extinction context to the acquisition context help to thwart renewal or is renewal thwarted only because the extinction context resembles the test context? (Renewal does not occur in ABB paradigms [e.g., Bouton & Bolles, 1979; Harris, Jones, Bailey, & Westbrook, 2000; Tamai & Nakajima, 2000]). We first addressed these questions in Experiments 3a and 3b. There, we directly compared ABA and AAB renewal under two levels of context similarity. Weaker AAB than ABA renewal might suggest that high similarity of the acquisition and extinction contexts helps thwart renewal, those contexts being the same only in the AAB case. We then pursued the question further in Experiment 4. There, we directly compared AAB, ABC, and ABA renewal. Weaker AAB than ABC renewal would again suggest that high similarity of the acquisition and extinction contexts helps thwart renewal, even when the acquisition and test contexts differ in both cases.

As in much prior work on fear renewal in rats, we used the barpress conditioned suppression task of Estes and Skinner (1941) to measure conditioned fear. The technique relies on the fact that rats barpressing for food tend to back away from the bar and become immobile during feared CSs that are given independently of their responding (Bevins & Ayres, 1992, 1994; Bouton & Bolles, 1980; Mast, Blanchard, & Blanchard, 1982). The suppression of barpressing that results from these behaviors provides an index of the strength of fear.

Experiments 1a and 1b

In both Experiments 1a and 1b, we used an ABA renewal paradigm (e.g., Bouton & King, 1983). In Experiment 1a, Contexts A and B were operant boxes distinguished by three features: (1) an odor (anise vs. vinegar), (2) their location in the room (north vs. south sides), and (3) unintended physical differences between copies of the same box at the two sites. In Experiment 1b, we eliminated the odor cue. We would have preferred to have varied the presence versus absence of the odor cue within a single experiment but were discouraged from doing so because of the problem of lingering odors.

Method

Subjects

In Experiment 1a, the subjects were 24 male albino rats, most of which had been trained to barpress for food pellets in an undergraduate laboratory at Smith College. On arrival at our colony at the University of Massachusetts, all were housed singly in hanging stainless steel and steel mesh cages with water always available. The room was lighted daily between 0600 and 2200 h. After the rats had spent about 2 months in the colony, their free feeding weights ranged from 458 to 620 g. We then reduced their ration of Lab Diet 5001 rodent chow to 3–5 g daily until they reached 80% of those levels, at which they were maintained. We conducted all training sessions between 1200 and 1700 h.

In Experiment 1b, the subjects were 24 experimentally naive male albino Sprague–Dawley rats, about 80 days old on arrival from Harlan Industries, Indianapolis, IN. After a week in our colony, they were reduced to and maintained at 80% of their free feeding weights, which ranged from 368 to 405 g. Animal housing and care procedures were unchanged.

Apparatus

Eight copies of an operant box (inside dimensions = $23.2 \times 20.3 \times 19.5$ cm) were placed in a 2.7×4.4 m room. These were housed in 0.61-m ventilated cubes of 12.7-mm thick plywood. One side of each cube was hinged to form a door, and all interior surfaces, including the door, were lined with acoustical tile. In Experiment 1a, we placed a glass furniture coaster containing 10 ml of an anise solution (2 parts McCormick pure anise extract and 98 parts tap water) near the dipper trays in Cubes 1–4. These four cubes, arranged linearly, always abutted the north wall of the room. In Cubes 5–8, we similarly placed a coaster containing 10 ml of undiluted Heinz distilled white vinegar (5% acidity). These four cubes, also arranged linearly, always abutted the south wall of the room. The opaque doors to the two sets of cubes faced each other about 1.3 m apart. The two sets of cubes served as Contexts A and B (counterbalanced). In Experiment 1b, we used the same apparatus but removed the odor cues that helped distinguish Context A from Context B.

The end walls of each operant box were aluminum; the sides and top were clear Plexiglas. Centered in one end wall was a response bar (5×1.5 cm) mounted 8 cm above the floor. A dipper tray (5×5.5 cm) was recessed in the lower left corner of this same wall. The floor comprised 18 stainless steel rods (2 mm diam.), centers spaced 1.3 cm apart. A high voltage, high resistance shock source, and relay scrambler (Hoffman & Fleshler, 1962) delivered a 0.5-mA, 1-s shock US to this floor.

On each box lid was a speaker (10-cm diam.) that provided background white noise of 85 dB. Sound intensity was measured using a Radio Shack sound level meter (catalog number 33-2050; C scale, slow response) with its microphone about 7 cm from the dipper tray.

A "lights-off" CS was provided by turning off two normally on white frosted bulbs (7.5 W and 110 V), mounted on the rear wall of the housing cube. When lit, these bulbs shone through the clear Plexiglas wall to the rat's right (north or south

depending on context) as it faced the bar. Throughout this report, all CSs were given independently of barpress responding and were 2-min long. Previous work with fear conditioning (Bevins & Ayres, 1991; Rauhut, McPhee, DiPietro, & Ayres, 2000, p. 105) found no evidence that stimulus termination of this duration is processed differently from stimulus presentation.

Barpressing, the baseline response to be suppressed by CSs, was reinforced by 4-s access to a 0.1-ml dipper cup of 32% liquid sucrose. A computer in another room controlled all programmed events and recorded responses.

Procedure

In both Experiments 1a and 1b, rats were randomly assigned to three groups: AAA, ABA, and FC ($ns = 8$). Group AAA received fear acquisition, extinction, and test phases, all in Context A. Group ABA was identical except that extinction was given in Context B. Group FC was a forgetting control group. Like Group ABA, it received acquisition and test in Context A and time in Context B; however, in Context B, it did not receive extinction but instead received only the barpress training that all groups received in all phases.

Preliminary training involved 2 days of training the rats to drink sucrose from lifted dippers (magazine training), 2 days of shaping their barpress behavior (each day with 90 reinforced responses), 4 days of training on a schedule that reinforced responding at variable intervals averaging 60 s (VI 60-s schedule), and 2 days of pre-testing the 2-min CS that would later co-terminate with shock. There were two pre-test trials per day. Beginning with Day 1 of VI training, all sessions were 1-h long, and the VI 60-s schedule was always in force. During the 10 days of preliminary training, we placed the rats in Context A on odd days and Context B on even days, thus familiarizing them with both contexts. During magazine training and shaping, we left the doors of the housing cubes open so as to see the rats. Hoping to minimize the blending of odors in the room in Experiment 1a, we did not use the anise and vinegar until Day 1 of VI training, when we closed the doors to the housing cubes for the first time. We followed this practice in all experiments.

Starting on the day after preliminary training, we gave the rats 5 days of fear acquisition in Context A. On each day, two response-independent exposures of the 2-min CS co-terminated with a 1-s, 0.5-mA scrambled grid shock US (CS + trials). CSs began no earlier than the start of Min 15 and no later than the start of Min 47. The mean intertrial interval (ITI) was 17.4 min (onset to onset).

Extinction was preceded by 1 day of VI training in the extinction context to ensure stable responding there at the start. Extinction itself lasted 8 days. For Groups AAA and ABA, it included 7 CS-alone (CS-) trials on Day 1 and 6 CS− trials on each remaining day with one exception: by mistake, Group AAA received only VI training on Day 8. In Experiment 1b, Groups AAA and ABA each received 6 CS− trials on each of the 8 days. CSs began no earlier than Min 11 and no later than Min 49. The mean ITI was 6.6 min. During this same phase in both experiments, Group FC received no programmed CSs but, like the other two groups, was allowed to barpress for sucrose on the VI schedule. Thus, this group served as a control for the forgetting of fear.

The test for renewal was prefaced by 1 day of VI training in Context A to ensure stable barpressing in preparation for testing. The test itself was given on the next 2 days, each with two CS− trials. CSs began at the start of Min 23 and 43 on Day 1 and Min 15 and 31 on Day 2. By Day 1 of renewal testing, the rats in Groups ABA and FC had spent nine sessions in Context A and 11 in Context B, counting from Day 1 of VI training when the odorants were first used. By the end of renewal testing, they had spent 11 sessions in each context.[1]

Measure of conditioned fear. A suppression ratio (Annau & Kamin, 1961) was used to index suppression to CSs. The ratio was defined as $D/(D+B)$, where D denotes the number of responses during the 2-min CS and B denotes the number in a 2-min period just before CS onset. Occasionally a rat failed to respond both before and during a CS. On such trials, we estimated the rat's suppression ratio by averaging its ratios on the immediately preceding and following trial in the phase of interest.[2] If there were two or more such trials in succession, we dropped the rat from the analysis of that phase. Hence the degrees of freedom associated with statistics that we report will occasionally be smaller than expected.

Statistical analyses. We subjected the data of most interest to Group × Trial analyses of variance (ANOVAs) and, when warranted, to follow-up contrasts. We used a two-tailed critical region of 0.05 throughout.

Results

The main result of Experiments 1a and 1b was that strong ABA renewal occurred in Experiment 1a, where an odor cue was provided to help differentiate the contexts, but not in Experiment 1b, where the odor cue was removed. In both experiments, the transfer of CS-fear from the acquisition context to the extinction context was perfect.

In each experiment, the acquisition of conditioned suppression in the three groups was similar and unremarkable. On the last day of acquisition, all groups suppressed strongly. During extinction, suppression weakened across trials on Day 1, only to recover at the start of Day 2 and again but less so at the start of Day 3. After Day 3, there was little suppression. Because of this data pattern, the results of extinction are presented with the focus on the first 3 days.

[1] Investigators often equate exactly the total exposure to Contexts A and B before testing for renewal (e.g., Bouton & King, 1983, Experiment 3). Here and elsewhere (Rauhut et al., 2001), we did not do so. We did, however, ensure that all rats received extensive exposure to each context. We also ensured that all rats received a full session of VI training before beginning renewal testing. We did so to reduce the odds that any unconditioned neophobia or excitation conditioned to the test context might influence the test results. It is not clear why equating experience with the contexts would necessarily eliminate either of these factors. Note too that, in an appetitive situation, Bouton and Peck (1989) directly compared the effects on renewal of equating versus not equating exposure to the contexts and found no difference. Finally, as the renewal paradigm is designed to model the therapeutic situation in humans, it is worth observing that the time spent in therapy with humans is never equated with the time spent outside it.

[2] No ratios were estimated in Experiments 1a, 1b, 2, 3b or 4. In Experiment 3a, less than 0.3% of the ratios were estimated during the acquisition phase and first 3 days of extinction.

Fig. 1 shows the results of both Experiments 1a (A) and 1b (B). In each panel, the data are plotted in six groupings. The leftmost grouping, at the point marked A, shows suppression on the last day of acquisition (mean of Trials 9 and 10). The next three groupings show suppression on each trial of extinction on Days 1, 2, and 3, respectively. Gaps in the plots separate the 3 days so as to show clearly the spontaneous recovery that occurred between days. The point marked L shows suppression on the last trial of extinction. The sixth grouping, at the far right, shows the results on the four renewal test trials.

In both experiments, one-way ANOVAs found no differences among groups on the last day of acquisition, Fs < 1. Group $\times$ Trial ANOVAs using all the trials of

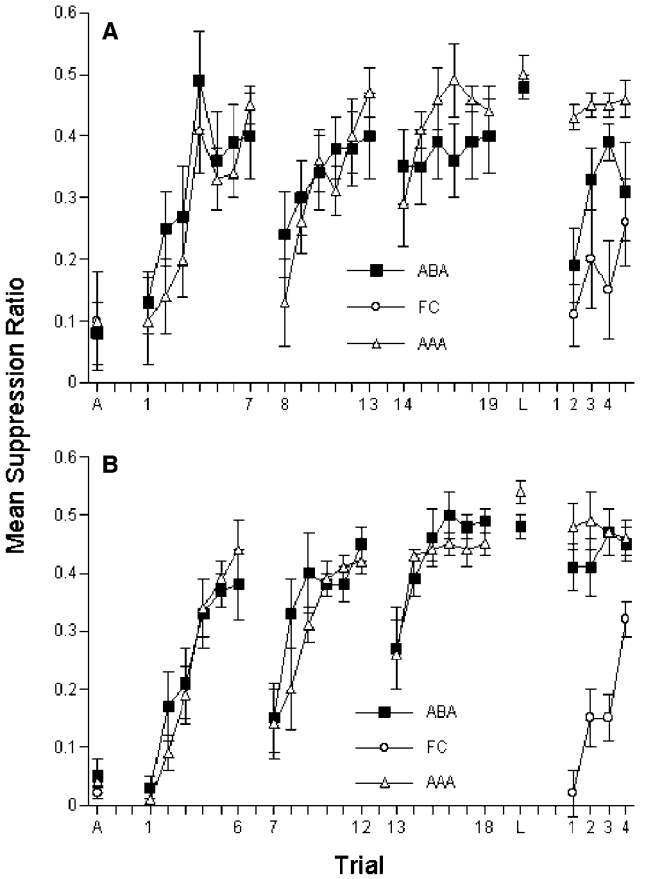

Fig. 1. Group mean suppression in Experiments 1a (A) and 1b (B). From left to right, the six groupings of data show suppression on the last day of acquisition (marked A), on all trials of Days 1, 2, and 3, respectively, of extinction, on the last trial of extinction (marked L), and on the four renewal test trials. In Experiment 1a, Contexts A and B differed in terms of odor, side of room, and unintended differences between copies of the same box at the two sites. In Experiment 1b, the odor cue was removed. Error bars show ± 1 SEM.

the first 3 days of extinction found significant effects of trial: in Experiment 1a, $F(18, 252) = 16.00$; in Experiment 1b, $F(17, 238) = 29.19$. This reflects the extinction of fear across trials. The effects of groups did not approach significance, Fs < 1. The Group $\times$ Trial interaction was significant in Experiment 1a, $F(18, 252) = 2.10$, but t tests performed on each trial revealed no significant difference between groups on any single trial, largest $t(14) = 1.54$, $p = .15$. On the last trial of extinction in Experiment 1a, there was no effect of group, $F < 1$; but, in Experiment 1b, Group ABA was significantly more suppressed than Group AAA, $F(1, 14) = 4.85$. That difference, however, appeared to be aberrant because a Group $\times$ Trial ANOVA on the data from all 48 extinction trials found neither a significant effect of group, $F < 1$, nor a Group $\times$ Trial interaction, $F < 1.05$. An important part of these results, in summary, was that Groups AAA and ABA responded similarly during extinction, even though Group ABA received extinction outside its acquisition context. Thus the transfer of CS-fear from Context A to Context B appeared to be perfect (cf. Bouton & King, 1983).

In Experiment 1a, a Group $\times$ Trial ANOVA on the data from the four renewal test trials found significant effects of group, $F(2, 21) = 11.00$, and trial, $F(3, 63) = 3.87$. A follow-up ANOVA isolating Groups AAA and ABA found only a significant effect of group, $F(1, 14) = 23.70$. A similar ANOVA isolating Groups ABA and FC found only a significant effect of trial, $F(3, 42) = 3.64$. These results suggest that strong renewal of conditioned fear occurred in Group ABA. Other studies of fear renewal (e.g., Bouton & King, 1983; Harris et al., 2000; Rauhut et al., 2001) have found that, despite the renewal of fear, there is usually evidence for transfer of extinction from the extinction context to the test context. That is, over the course of nonreinforced renewal testing, Group ABA shows a faster loss of fear than does the forgetting control group. We found a trend in this direction, but it was not statistically significant.

In Experiment 1b, a similar ANOVA of the renewal test data revealed significant effects of group, $F(2, 21) = 30.01$, trial, $F(3, 63) = 5.45$, and Group $\times$ Trial, $F(6, 63) = 4.74$. Unlike Experiment 1a, an ANOVA isolating Groups AAA and ABA found no significant effects, Fs < 1.13, and an ANOVA isolating Groups ABA and FC found significant effects of group, $F(1, 14) = 27.84$, trial, and Group $\times$ Trial, Fs$(3, 42) > 4.27$. Thus, there was no evidence for ABA renewal when, in Experiment 1b, the odor cue was removed and did not help to differentiate the two contexts.

Between-experiment comparisons are always hazardous, and we know that suppression can vary across shipments of rats and times of year (Kamin, 1965, pp. 120–121). Our confidence in such comparisons can be strengthened, however, if it can be shown that the only group that differs across experiments is the group that might reasonably be affected by the variable of theoretical interest (here, Group ABA is the only group whose behavior might reasonably depend upon the presence vs. absence of the odor cue). To this end, we performed Group $\times$ Trial ANOVAs isolating first the AAA groups of Experiments 1a and 1b, then the FC groups, and finally the ABA groups. These ANOVAs found no significant effects for the two AAA groups, largest $F(1, 14) = 2.09$, $p = .17$ (Group effect), and only significant effects of

trial for the two FC groups, $F(3,42) = 11.69$. In contrast, for the two ABA groups, the effects of group, $F(1,14) = 8.83$, and trial, $F(3,42) = 3.06$, were both significant. Most important is the effect of group, which indicates that renewal was stronger in Experiment 1a, where an odor cue was provided to help differentiate the contexts, than in Experiment 1b, where an odor cue was absent. The analysis suggests that making the A and B contexts more similar by removing the odor cue in Experiment 1b significantly weakened renewal.

In both experiments, a Group × Trial ANOVA was also performed on the pre-CS rates during the crucial test for renewal. Of most importance, no effects involving group were significant, meaning that group differences in conditioned suppression were not complicated by group differences in pre-CS rates. In Experiment 1a, the mean pre-CS rates for Groups AAA, ABA, and FC were 23, 32, and 22 responses per minute, respectively. In Experiment 1b, the corresponding means were 24, 26, and 21.

Discussion

In Experiment 1a, we found strong renewal of conditioned fear in an ABA renewal paradigm when the A and B contexts differed in terms of only their odor, their location in the room, and unintended differences between copies of the same box at the two locations. In Experiment 1b, we found no renewal when the odor cue was removed. In both experiments, the transfer of CS-fear from the acquisition context to the extinction context was perfect, and the results of Experiment 1a, in particular, were consistent with those of Bouton and King (1983) in showing such perfect transfer coupled with strong ABA renewal.

The results of our AAA treatment in Experiment 1a speak with unusual force against a "spontaneous recovery" account of ABA renewal. This is because we accidentally failed to give any CS− trials to Group AAA on the last day of extinction. Thus, Group AAA received less extinction than Group ABA and had an extra day intervene between its last extinction trial and first test trial. Other things being equal, both of these factors in principle should have led to more spontaneous recovery between extinction and renewal testing in Group AAA than in Group ABA. The fact that no such recovery was evident in Group AAA therefore indicates that the strong suppression in Group ABA on the first test trial could not have been due to spontaneous recovery.

The failure of Group AAA in Experiment 1a to differ from Group AAA in Experiment 1b was not at all unexpected, even though the two groups received somewhat different numbers of CS− trials in extinction: 43 in Experiment 1a versus 48 in Experiment 1b. In an ABA group, Rauhut et al. (2001), using procedures similar to ours, found no difference in the effects of 20 versus 100 extinction trials, and the difference between 43 and 48 is well within that range.

A methodological implication of our finding of ABA renewal in Experiment 1a is that workers seeking to study renewal of conditioned fear do not need elaborate differences between their A and B contexts. Separate rooms for the contexts are unnecessary (cf. Bouton & King, 1983; Harris et al., 2000), as are separate transport

devices (cf. Rauhut et al., 2001). One need not even use different types of chambers. Our findings should encourage the study of renewal in laboratories with only one procedure room or only one type of box.

A clinical implication of the work is that clinicians seeking to avoid the problem of relapse may fail even if their extinction and acquisition or extinction and test contexts differ in terms of only a few features.

Our results also speak to a theoretical account of renewal suggested by Lovibond, Preston, and Mackintosh (1984). They proposed that the CS might look or sound different in Context A versus Context B. Such a difference might be especially likely if the two contexts differed in size, shape, or construction materials. In that case, the CS that was extinguished might look or sound different from the CS that was conditioned. Extinction would not generalize completely to the original CS, thus explaining why, in an ABA paradigm, the CS once again evokes a CR when tested in the original acquisition context. Experiment 1a minimized this prospect because the two contexts were of the same size and shape and were made from the same materials. Still, it is conceivable that subtle, unintended differences between the contexts on the two sides of the room could have altered the CS's appearance. If those CS differences caused the renewal found in Experiment 1a, then the same differences would have existed in Experiment 1b, and renewal should have occurred there too. The fact that it did not means that the renewal found in Experiment 1a cannot be explained in terms of the "different CS" hypothesis.

Related to this issue is the possibility that unintended differences between boxes at the two sites helped the rats distinguish between the A and B contexts. For example, the levers in the two contexts may have required more or less force or travel to depress a microswitch. Dippers may have risen slower or faster or to a slightly different height below the dipper tray. The rat may have relied on other physical differences between contexts not evident to us. The absence of renewal in Experiment 1b tends to minimize the import of such cues.

Since renewal did not occur in Experiment 1b when odor was *not* used to distinguish the contexts, it seems likely that odor was the controlling factor in Experiment 1a. However, another possibility is that no *one* factor sufficed to produce renewal; rather, renewal was produced by two or more factors in concert. We examined these ideas in Experiment 2.

Experiment 2

Here, we tried to assess the role of three contextual distinctions in various combinations: odor, side of room, and unintended differences between copies of the same box. A major methodological concern was the problem of odor blends. To minimize blending, we decided to change odorants only between days, airing out the room and boxes overnight. Thus, we never deliberately scented a given context with both anise and vinegar on the same day. This strategy was not entirely successful because we could usually detect residual odors the next day. The strategy also constrained our

manipulations. Under these constraints, we studied three variants of an ABA renewal procedure and included a forgetting control group.

The three variants were represented by Groups O, OB, and OSB. The letters denote what changed between acquisition and extinction phases. For Group O, only the odor changed; the side of room and box were constant. It is important to recognize the nature of the odor change. For example, if anise was present during acquisition, it was replaced by vinegar on the 1st day in the extinction context. The resulting odor might be described as *aV*. Here, *a* denotes the residual odor of anise from the prior phase, and *V* denotes the odorant actually placed in the box on that day. This contrasts with the change in odorants that occurred in Experiment 1a. There, when a rat was moved from a box containing anise to one containing vinegar, its vinegar box had never contained anise; therefore, its new odor would be described as *V*, not *aV*. For Group OB, the odor was changed as was the box, but the side of the room was held constant. For example, the rats in (north side) Boxes 1, 2, 3, and 4 that received acquisition in anise then received extinction in Boxes 4, 3, 2, and 1, respectively, and the anise was replaced by vinegar. The resulting new odor might again be described as *aV*. For Group OSB, the rats in (north side) Boxes 1, 2, 3, and 4 that received acquisition in anise then received extinction in (south side) Boxes 5, 6, 7, and 8, respectively, and the odor of anise moved with them. However, since Boxes 5–8 contained vinegar in the acquisition phase, the resulting new odor in extinction might be described as *vA*.

In sum, all three ABA renewal groups experienced some sort of change in odor between acquisition and extinction. In addition, Group OB received a change in box but not side of room, and Group OSB received a change in both box and side of room. In general, the more letters in the group name, the more the context changed between acquisition and extinction. The forgetting control group, Group FC, was identical to Group O except that it received only continued VI training during the extinction phase in Context B rather than fear extinction.

Method

Subjects and apparatus

The subjects were 32 experimentally naive rats from the same shipment as those in Experiment 1b. Their free-feeding weights ranged from 410 to 496 g at the start of deprivation, and they were maintained at 80% of this initial level. Animal care and housing were unchanged, as was the apparatus.

Procedure

The procedure replicated that of Experiment 1b except for the just-described methods of changing the contexts between phases.

Results

The main result of Experiment 2 was that renewal did not occur in Group O, which received only an odor change to distinguish Contexts A and B; nor was

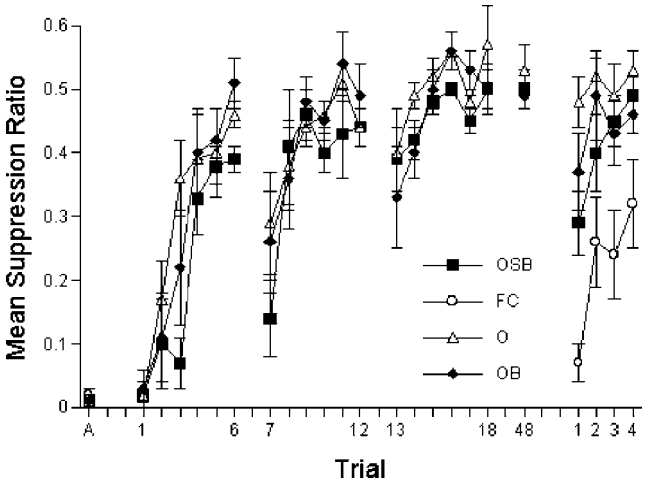

Fig. 2. Group mean suppression in Experiment 2. The data are shown in the same six groupings as in Fig. 1, except that the last trial of extinction is depicted as Trial 48. Group designations O, OB, and OSB (odor, side of room, and box) represent features that distinguished Contexts A and B. Error bars show ± 1 SEM.

renewal significant in Group OB, which received an odor change and a change in box but not side of room; however, renewal did occur in Group OSB, which received a change in odor, side of room, and box. Transfer of CS-fear from the acquisition context to the extinction context was not detectably different in the three groups.

Fig. 2 plots the results according to the same scheme as in Fig. 1. Here, however, the last trial of extinction is shown as Trial 48.

One-way ANOVAs found no differences among groups on the last day of acquisition or on the first or last trials of extinction, Fs < 1. Similarly, a Group $\times$ Trial ANOVA on the suppression across all 18 trials of the first 3 days of extinction found only the effects of trial to be significant, $F(17, 306) = 36.96$. The effects of group and Group $\times$ Trial did not approach significance, Fs < 1.12.

Group O showed the weakest suppression of all the groups during renewal testing. Because there was no AAA control group to contrast against Group O, the only way to determine whether Group O showed renewal was to contrast its performance on Trial 1 of renewal testing with that on the last trial of extinction. A correlated t test contrasting these performances yielded $t < 1$, suggesting no evidence of renewal in that group. Subsequent analyses, therefore, treated Group O as if it were an AAA control. A Group $\times$ Trial ANOVA on the data from the four renewal test trials found significant effects of group, $F(3, 28) = 7.72$, trial, $F(3, 84) = 19.35$, and Group $\times$ Trial, $F(9, 84) = 2.57$. A follow-up ANOVA isolating Groups O and OB found only a significant effect of trial, $F(3, 42) = 4.41$, implying that Group OB did not show significant renewal relative to Group O. A second follow-up ANOVA isolating Groups O and OSB found significant effects

of trial and Group × Trial, $Fs(3, 42) > 4.29$, and an effect of group that approached significance, $F(1, 14) = 4.03$, $p = .064$. The interaction suggests that Group OSB did show significant renewal relative to Group O. A final follow-up ANOVA isolating Groups OSB and FC found significant effects of group, $F(1, 14) = 7.99$, and trial, $F(3, 42) = 17.01$. The effect of group suggests that, even though Group OSB showed substantial renewal, it also showed a transfer of extinction from Context B to the test context, A (cf. Bouton & King, 1983; Harris et al., 2000; Rauhut et al., 2001).

A Group × Trial ANOVA was also performed on the pre-CS rates during renewal testing. Of most importance, no effect involving groups was significant, implying that differences among groups in terms of suppression ratios were not complicated by differences in pre-CS rates. Averaged over all four trials, the mean pre-CS rates for Groups O, OB, OSB, and FC, respectively, were 13, 17, 15, and 16 responses/min.

Discussion

Renewal did not occur when the A and B contexts differed only in terms of odor or in terms odor and box but not side of room. However, when odor differences were added to side-of-room differences and unintended differences in boxes (Group OSB), renewal was obtained. It was as though odor and location/box each produced a below-threshold renewal effect but when combined pushed the effect above threshold. Although Group OSB did show renewal relative to Group O, the two groups did not differ in their suppression during extinction. This again is similar to effects found by others (e.g., Bouton & King, 1983) in that groups that behaved differently in renewal testing behaved similarly during extinction. Transfer of CS-fear from the acquisition context to the extinction context appeared to be just as good in Group OSB, for which the A and B contexts differed the most, relative to Group O, for which the two contexts differed the least.

The absence of renewal when the A and B contexts differed only in terms of odor or only in terms of odor and unintended box differences, suggests that as context B comes to resemble Context A, an ABA renewal paradigm becomes an AAA paradigm. The results imply that relapse can be thwarted by extinguishing fear in a context highly similar to the acquisition or test context. There is other evidence that renewal does not occur in ABB paradigms (e.g., Bouton & Bolles, 1979; Harris et al., 2000; Tamai & Nakajima, 2000). Thus, renewal may have been thwarted only because the extinction context resembled the test context. In an ABA renewal paradigm, however, if the extinction context resembles the test context, it also resembles the acquisition context. In Experiments 3a and 3b, we asked whether that latter resemblance might be important. We did so by directly comparing the strengths of ABA and AAB renewal in each experiment. This comparison is of interest because the extinction context is identical to the acquisition context in the AAB case but not the ABA case. If AAB renewal turns out to be weaker than ABA renewal, that might suggest that making the extinction context resemble the acquisition context can reduce relapse.

Experiments 3a and 3b

To meet our goals, we needed to use contexts capable of producing detectable renewal. In Experiment 3a, we used the contexts of Experiment 1a. We knew we could detect renewal with these contexts; yet, differences between them were few. Thus, Contexts A and B were once again distinguished in terms of only their odor, side of room, and unintended differences in copies of the same box. It is important to note that between the end of Experiment 2 and the start of Experiment 3a, we allowed the laboratory to air out for over 60 days so as to minimize in Experiment 3a any blending of residual odors from Experiment 2.

In Experiment 3b, we used an entirely separate laboratory, one devised by Rauhut et al. (2001) to maximize differences between Contexts A and B.

Together, Experiments 3a and 3b were designed to compare directly the strengths of ABA and AAB renewal under two different degrees of context similarity. In each experiment, the test contexts were physically identical for both groups (e.g., half the rats in each group were tested in anise and half were tested in vinegar). Thus, it is probably more accurate to describe the AAB treatment as AAC and to describe the ABA treatment as CAC. This description makes it clear that the test context for both groups was physically the same. The rats in both groups were also tested in their extinction context, where no renewal was expected. The order of these tests was counterbalanced. The difference between fear in the extinction context, where renewal was not expected, and fear in Context C, where renewal was expected, thus provides a within-subject measure of renewal. Bouton and Ricker (1994) used a similar technique to demonstrate AAB renewal. That demonstration was clinically important because it meant that making the extinction context identical to the acquisition context was not sufficient to abolish relapse. Making the extinction context identical to the acquisition context, however, might have had some therapeutic benefit, but we cannot tell that because, unlike Experiments 3a and 3b, Bouton and Ricker did not directly compare the strengths of AAB and ABA renewal. The extinction and acquisition contexts are identical in the AAB case but not in the ABA case. If AAB renewal turns out to be significantly weaker than ABA renewal, then we might conclude that making the extinction context resemble the acquisition context helps to thwart renewal. Alternatively, if AAB and ABA renewal are similar in magnitude, then there would seem to be little therapeutic benefit to equating the extinction and acquisition contexts.

Method

Subjects

The subjects were 64 experimentally naive rats similar to those of Experiment 2. Their free feeding weights ranged from 320 to 370 g, and the rats were reduced to and maintained at 80% of those levels. Housing and animal care were unchanged.

Apparatus

For Experiment 3a, the apparatus was unchanged except that the background noise intensity was lowered from 85 to 80 dB to match that used in Experiment 3b. For Experiment 3b, a different laboratory was used, one with many more contextual differentiations. The room was similar to the one previously described, as were eight copies of an operant box and associated housing cubes. However, we modified four of these boxes to create two sets of four that we shall describe as Contexts A and C (counterbalanced). Boxes in Set 1 resembled those already described and were scented with anise. At the start of each session beginning with Day 1 of VI training, clear Plexiglas, sound-attenuating doors were inserted into the front of their housing cubes. Rats were carried from the colony to this context in a case that rested on a cart. The case was divided into cells ($21.4 \times 24.0 \times 15.4$ cm), each with a wire mesh floor, metal walls, and Plexiglas lid.

Boxes in Set 2 were modified to look, feel, and smell different from those in Set 1 in several ways. First, Set 2 was separated from Set 1 by a blackout cloth that split the room in half. Second, the fluorescent ceiling light in the half of the room housing Set 2 was removed, making that half much dimmer than the other half. Third, a metal plate was placed in each box so as to form a slanted back wall. It reduced the distance from the work panel to the back wall at floor level from 23.2 to 12.5 cm. Fourth, the work panel was covered with white Formica with vertical black stripes (1 cm wide, spaced 1.5–2.0 cm apart). Cutouts in the Formica allowed access to the bar and dipper. Fifth, four vertical black stripes (18 mm wide) were added to the outside of the Plexiglas walls to the left and right of the bar by taping strips of electrical tape about 3 cm apart. Sixth, the boxes were scented with vinegar. Seventh, at the start of the session, the wooden doors of their housing cubes were closed. Rats were carried from the colony to these boxes in their home cages, which were placed within a two-level wooden shelf unit that rested on a cart.

Other than the differences described above, the apparatus in the two laboratories was similar with the following exception. In Experiment 3a, the US was a 1-s 0.5-mA shock provided by Hoffman–Fleshler relay scramblers. In Experiment 3b, the US was a 1-s 0.6-mA scrambled grid shock provided by Grason–Stadler shocker/scramblers (Models 1064 or 700).[3] (Previous experience led us to believe that the behavioral effects of these two shock values would be highly similar, and this belief was supported by data presented below.)

Procedure

Rats were randomly assigned to Experiments 3a and 3b and to two groups ($ns = 16$) within each experiment. A single experimenter ran the two experiments concurrently. Except for the changes in experimental design described above, the procedure of both experiments replicated that of Experiment 2 through the end of

[3] For several years, these scramblers produced readings at the grids lower than the nominal values. However, prior to this experiment, the scramblers were sprayed with a cleaning solvent (DeoxIT D5, Caig Laboratories). Readings subsequently taken at the grids with a multimeter (Radio Shack, catalog number 22-805) revealed peak currents that approximated the nominal value.

the extinction phase. On the day following that phase, half the rats in Group AAC and half the rats in Group CAC received 1 day of further VI training in their extinction context and half received it in Context C. This ensured that barpress response rates would be stable at the start of renewal testing in the same context on the next day. On the day following the renewal test, the rats were given VI training in the opposite context. And on the last day of the experiment, they were tested for renewal in that opposite context. As before, in each renewal test session, there were two CS− trials.

Results

The main results of Experiments 3a and 3b were that both ABA (CAC) and AAB (AAC) renewal occurred but ABA renewal was stronger. The addition of other context distinctions in Experiment 3b to the three used in Experiments 1a and 3a did not detectably enhance either form of renewal. However, those additional context distinctions did reduce the transfer of CS-fear from the acquisition context to the extinction context for Group CAC. Thus, in Experiment 3b, with its many context distinctions, the transfer of CS-fear from Context A to Context B was, for the first time in this research, less than perfect.

Fig. 3 presents the results of Experiments 3a (A) and 3b (B) in similar groupings as in previous figures. The last trial of extinction is Trial 48. The renewal test results for Group AAC are shown in the sixth (second to last) grouping, and the results for Group CAC are shown as the seventh (rightmost) grouping. For both groups, open symbols at the right of the figure show the results of renewal testing in the extinction context, and solid symbols show the results of renewal testing in Context C.

Because Experiments 3a and 3b were done in part to study the effects of two degrees of context similarity on two forms of renewal, we were concerned about the slight difference in shock intensity that was confounded with this variable (0.5 mA in Experiment 3a and 0.6 mA in Experiment 3b). We therefore carefully compared both the acquisition and extinction of suppression across the two experiments for evidence of a shock intensity effect. Examination of the acquisition functions for Groups AAC and CAC in the two experiments (not shown) suggested they were very similar. Moreover, a Group × Experiment × Trial ANOVA of the acquisition data revealed only significant effects of trial, $F(9, 531) = 211.61$, reflecting the acquisition of suppression across trials. Importantly, there were no effects of experiment or interactions involving experiment, Fs < 1. An Experiment × Trial ANOVA was then performed using the extinction data plotted in Fig. 3a and b but only from the AAC groups of the two experiments. It too failed to reveal an effect of experiment, $F < 1$. The Experiment × Trial interaction, however, was significant, $F(17, 510) = 1.64$, but it seemed to reflect only a random crossing of the two AAC groups' curves; t tests conducted separately for each of the 18 trials found a significant difference between the two experiments only on Trial 17, $t(30) = 3.02$, which is not where one would expect a shock effect to appear. Thus, the analyses of both the acquisition and the extinction data suggest that the shocks used in the two experiments had very similar behavioral effects, as we expected.

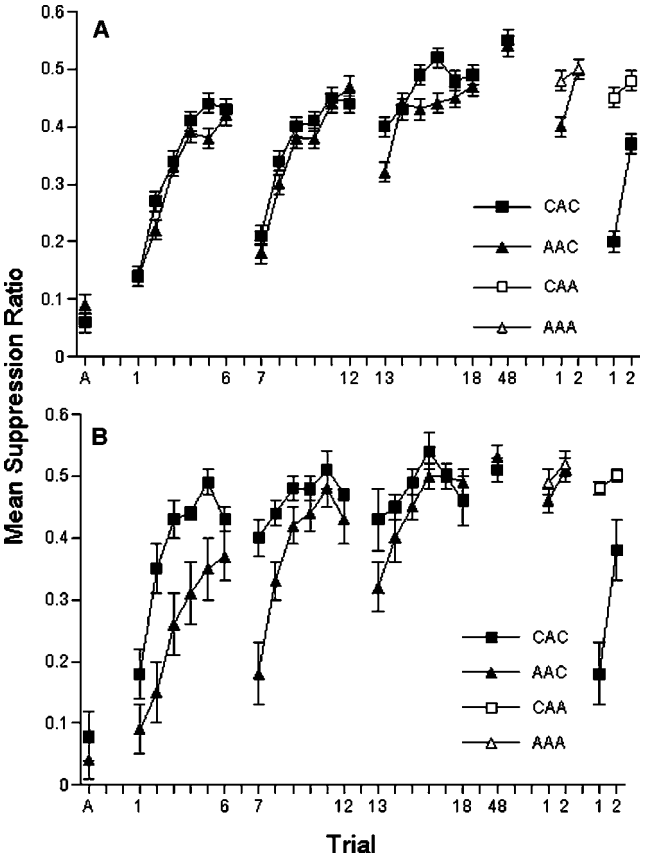

Fig. 3. Mean suppression in Experiments 3a (A) and 3b (B). The first five groupings of data in each panel resemble those in Figs. 1 and 2. From left two right, the last two groupings show, respectively, the renewal data for Groups AAC and CAC. Here, open symbols show the results of testing for renewal in the extinction context, where no renewal was expected, and solid symbols show the results of testing for renewal in Context C, where renewal was expected. For each group, the difference between its open and solid symbols provides a within-subject measure of renewal. Error bars show ± 1 SEM.

In each experiment, Groups AAC and CAC did not differ on the last day of acquisition or on the last trial of extinction, Fs < 1.

Group × Trial ANOVAs using the data of all the trials of the first 3 days of extinction revealed the following. In Experiment 3a, with its few context distinctions, only the effect of trial was significant, $F(17, 510) = 26.12$. The effects of group and Group × Trial did not approach significance, Fs < 1.14. This indicates, once again, that CS-fear transferred perfectly from Context C to Context A in Group CAC. In contrast, in Experiment 3b, with its many context distinctions, not only was the effect of trial significant, $F(17, 510) = 29.94$, but so too were the effects of group, $F(1, 30) = 9.13$, and Group × Trial, $F(17, 510) = 3.71$. Thus, for the first time in this

research, suppression was weaker in the group (Group CAC) that received extinction outside its acquisition context.

In renewal testing, both Groups AAC and CAC showed weak suppression when tested in their extinction context. To search for any evidence of renewal in the extinction context, we performed a Group × Trial ANOVA using the last trial of extinction and the first trial of renewal testing in the extinction context. This ANOVA found no significant effects, Fs < 1, suggesting that both groups performed similarly on the two trials and that neither showed renewal in the extinction context.

Next, we performed a mixed-design ANOVA in which the between-subject factors were experiment and group (AAC vs. CAC). Within-subject factors were trial and test context (Context C vs. extinction context). This analysis found a significant effect of test context and a Context × Group interaction, $F\text{s}(1, 60) > 23.19$. These effects indicate, first, that renewal occurred in the two groups combined and, second, that it was stronger in Group CAC than in Group AAC. Neither effect interacted with experiment, Fs < 1. To see if each form of renewal was significant, we performed a follow-up Experiment × Trial ANOVA using only the CAC rats. It found significant CAC renewal (more suppression following the CAC procedure than the CAA procedure), $F(1, 30) = 42.05$. This effect did not interact with experiment, $F < 1$. A second, similar, ANOVA using only the AAC rats also found significant renewal (more suppression following the AAC procedure than the AAA procedure), $F(1, 30) = 9.39$, and this effect likewise failed to interact with experiment, $F(1, 30) = 2.10$, $p = .16$. Thus, renewal was significant for both AAC and CAC conditions.

An ANOVA like the first in the preceding paragraph was also performed on the pre-CS rates from the renewal tests. Of most interest, the effect of test context did not reach significance, $F(1, 60) = 1.94$, $p > .16$, meaning that the renewal effect described above was not complicated by differences in response rate when rats were tested in their extinction context or in Context C (Ms $= 20$ and 17 responses per min, respectively). Furthermore, no interactions involving context approached significance, Fs < 1.

Discussion

Experiment 3a demonstrated both ABA and AAB renewal with few distinctions between Contexts A and B. Those distinctions included odor, side of room, and unintended differences between copies of the same box at the two sites. Experiment 3b, conducted by the same experimenter concurrently with Experiment 3a, added further distinctions between contexts, including presence versus absence of striped walls, presence versus absence of a slanted (and space reducing) back wall, location in the bright versus dim halves of the room, type of door that sealed the housing chamber, and type of transport device. Perhaps surprisingly, these additional context differences did not significantly enhance either type of renewal. The possibility exists that if one or more context differences are

particularly salient, it or they may overshadow other differences. An alternative possibility is that this lack of effect is akin to the flattening of stimulus generalization gradients frequently seen at the extremes of a stimulus continuum (e.g., Domjan, 2003, Chapter 8). This idea is consistent with a theory of renewal advanced by Bouton (1993). According to the theory, extinction causes inhibition to build up until it balances excitation, which itself remains fully intact. When the test context differs from the extinction context, the inhibition suffers more generalization decrement than does the excitation, leading to renewal. Our data can be taken to imply that the generalization decrement of inhibition is great with just a few salient differences between contexts, but that additional differences (analogous to changes at the extremes of a stimulus continuum) cause little further decrement.

There have been several attempts to demonstrate AAB renewal of conditioned fear. Bouton and King (1983) and Bouton and Swartzentruber (1989) failed to find it but, in the same papers, reported evidence of ABA renewal. Tamai and Nakajima (2000) found ABA and AAB renewal effects of similar magnitude (both statistically significant) after 18 days of extinction but found that only the ABA renewal effect withstood 28 days of extinction. In an appetitive operant paradigm, Nakajima, Tanaka, Urushihara, and Imada (2000) found ABA but not AAB renewal. Likewise, in a goal tracking paradigm in which a food pellet US signaled additional food USs, Goddard (1999) found ABA but not AAB renewal. Bouton and Ricker (1994) reported AAB renewal in fear conditioning but did not compare its magnitude with that of ABA renewal. In general, the overall impact of the foregoing is that AAB renewal appears to be real but much weaker than ABA renewal. The present findings strongly support that conclusion. They seem to provide the clearest demonstration of a statistically significant AAB renewal effect concurrent with a significantly larger ABA renewal effect. It may be noteworthy that two of the three experiments that demonstrated AAB renewal did so using within-subject designs (Bouton & Ricker, 1994; present work). All of the experiments that failed to do so used between-group designs.

The finding that AAB renewal is weaker than ABA renewal is consistent with the idea that making the extinction context identical to the acquisition context weakens renewal. However, the finding does not demand that conclusion. Another possibility is that the similarity of those two contexts is irrelevant and that AAB renewal is weaker than ABA renewal only because the acquisition and test contexts are identical in the ABA case but not the AAB case. To test this hypothesis, we performed a final experiment, in which we directly compared the strengths of AAB, ABA, and ABC renewal. If the similarity of the acquisition and extinction contexts is irrelevant and only the similarity of the acquisition and test contexts is important in producing strong renewal, then AAB and ABC renewal should be equally weak, relative to ABA renewal because in both AAB and ABC cases the acquisition and test contexts differ. However, if the similarity of the acquisition and extinction contexts is important in thwarting renewal, then AAB renewal should be weaker than ABC renewal because only in the AAB case are these two contexts identical.

Experiment 4

In Experiment 4, we directly compared the strengths of AAB, ABC, and ABA renewal, using within-subject designs similar to those of Experiments 3a and 3b. As in those experiments, however, all rats were tested for renewal in the same physical context. To make that clear, we describe the three paradigms as AAC, ABC, and CAC. As in Experiments 3a and 3b, each rat in the experiment was tested twice for renewal: once in Context C, where renewal might be expected, and once in its extinction context, where renewal was not expected. As before, the order of these two tests was counterbalanced.

After Experiments 3a and 3b were completed, the laboratory was moved from the University of Massachusetts, Amherst to Baldwin-Wallace College, Berea, OH, and Experiment 4 was conducted there.

Method

Subjects

The subjects were 48 experimentally naive male albino rats obtained from Zivic-Miller Laboratories (Zellenople, PA). Their free feeding weights ranged from 424 to 590 g, and the rats were reduced to and maintained at 80% of those levels. Housing and animal care were unchanged.

Apparatus

The operant chambers were 16 boxes like those described in Experiment 3a. However, they were placed in ventilated housing cubes (internal dimensions = $55.9 \times 55.9 \times 48.9$ cm) made of Ultra Plus foam core with a 1-mm PVC facer (United Industries, Bentonville, AR). Eight boxes were placed in each of two rooms. Four of the boxes in Room 1 (2.5×5.7 m) were scented with anise, and four were scented with vinegar as in our previous experiments. Four of the boxes in Room 2 (3.2×5.0 m) were scented with undiluted Pine Sol (Clorox, Oakland, CA), and four were scented with four parts of coconut extract (McCormick, Hunt Valley, MD) mixed with 96 parts of water. Sixteen Grason–Stadler shock sources and scramblers like those used previously were set at 0.6 mA and produced a peak current of that value measured at the grids with a Fluke 83 III multimeter (John Fluke Mfg., Everett, WA). In each room, four of the boxes were stacked 2×2 on a bench top affixed to the north wall, and four were similarly stacked on the adjacent west wall. A 2.5-cm sheet of foam insulation separated top and bottom boxes to reduce any cross talk between them. Adjacent boxes were a minimum of 20 cm apart.

Procedure

Rats were randomly assigned to each of three groups: AAC, CAC, and ABC ($ns = 16$). The procedure was similar to that of Experiment 3a. Preliminary training, resembling that of earlier experiments, included 3 days of magazine training, 3 days of shaping, 3 days of VI training, and 3 days of pre-exposure to the lights-off CS. Since Group ABC was to experience three contexts during the course of acquisition,

extinction and renewal testing, each rat during preliminary was exposed to each one of these contexts in each one of these 3-day cycles. As in Experiment 1a, the contexts differed in terms of odor, location, and unintended differences in copies of the same box.

In each of the acquisition, extinction, and test phases, four rats in each group of 16 were assigned to each of the four odors. For rats in Group AAC, the odors (boxes/locations) were constant across the acquisition and extinction phases. Rats in Groups CAC and ABC were placed in a different odor (box/location) for extinction. For example, rats conditioned in anise received extinction in vinegar (and vice versa), and rats conditioned in Pine Sol received extinction in coconut (and vice versa). Following extinction came renewal testing. All rats received two tests for renewal, one in their extinction context and one in Context C. For rats in Groups AAC and ABC, that C context (odor/box/location) had not previously been experienced in acquisition or extinction, but for Group CAC, that C context was the context of acquisition. As in Experiments 3a and 3b, the order of the two renewal tests was counterbalanced, and each renewal test was preceded by a day of VI training in the appropriate test context in preparation for that testing. Other procedural details, including the number of acquisition, extinction, and renewal test trials, were as in Experiments 3a and 3b.

Results

The main finding of Experiment 4 was that renewal was significant in all three groups but was weaker in Group AAC than in Groups ABC and CAC. The latter two groups did not differ. Transfer of fear from the acquisition context to the test context was slightly but not significantly stronger in Group AAC than in the other two groups.

Fig. 4 presents the results of Experiment 4 in similar groupings as in previous figures. The last trial of extinction is Trial 48. The rightmost three groupings of data show the results of renewal testing. From left to right, those three groupings are from Groups AAC, ABC, and CAC, respectively. For each group, open symbols at the right of the figure show the results of renewal testing in the extinction context, and solid symbols show the results of renewal testing in Context C.

During the acquisition phase, all three groups acquired conditioned suppression at the same rate, and, as shown at the point marked A, performed similarly on the last day, $F < 1$.

Over the first 3 days of extinction, all three groups showed the usual pattern of weakening suppression within days and spontaneous recovery between days. Seeking evidence for imperfect transfer of fear from the acquisition context to the extinction context, we pooled Groups CAC and ABC, which both received extinction outside the acquisition context ($n = 32$), and, using a Group $\times$ Trial ANOVA, contrasted them against Group AAC ($n = 16$), which received extinction in the acquisition context. Although there was a tendency for the pooled groups tested outside the acquisition context to show weaker suppression, this tendency (group effect) did not reach significance, $F(1, 46) = 3.49$, $p = .07$; nor did the Group $\times$ Trial interaction,

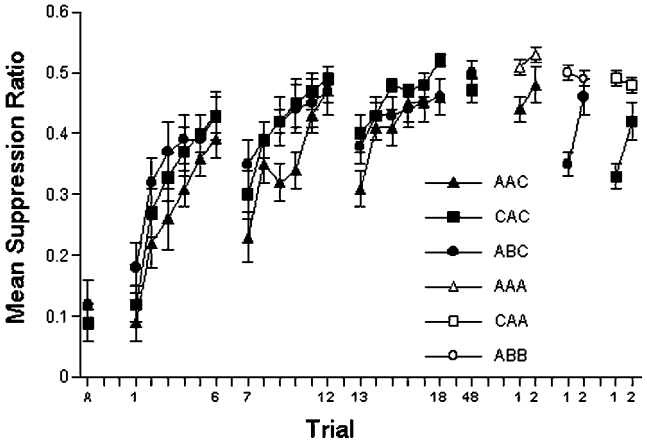

Fig. 4. Mean suppression in Experiment 4. The first five groupings of data resemble those in Figs. 1–3. From left to right, the last three groupings show, respectively, the renewal data for Groups AAC, ABC, and CAC. Here, open symbols show the results of testing for renewal in the extinction context, where no renewal was expected, and solid symbols show the results of testing for renewal in Context C, where renewal was expected. For each group, the difference between its open and solid symbols provides a within-subject measure of renewal. Error bars show ± 1 SEM.

$F(17, 782) = 1.44$. The only significant effect was the effect of trial, $F(17, 782) = 43.33$. Thus, even with an unusually large sample size, there was no significant evidence that fear acquired in the acquisition context suffered generalization decrement when assessed outside that context.

In renewal testing, all three groups showed weak suppression when tested in their extinction context. To search for any evidence of renewal in the extinction context, we performed a Group $\times$ Trial ANOVA using the last trial of extinction and the first trial of renewal testing in the extinction context. This ANOVA found no significant effects, largest $F(2, 45) = 1.29$, $p = .29$, suggesting that all three groups performed similarly on the two trials and that none showed renewal in the extinction context. Next, we performed a Group $\times$ Context (extinction context vs. Context C) ANOVA using just the data from Trial 1 of renewal testing (there being little suppression on Trial 2 in any group). This ANOVA found significant effects of context, $F(1, 45) = 82.6$, group, and Group $\times$ Context, Fs$(2, 45) > 4.33$. Next, a follow-up ANOVA isolating Groups ABC and CAC found only a significant effect of context, $F(1, 30) = 78.4$. This indicates that the two groups combined showed renewal in Context C and that the size of the renewal effect in the groups was similar. Next, an ANOVA isolating Groups ABC and AAC found significant effects of context, $F(1, 30) = 37.38$, group, and Group $\times$ Context Fs$(1, 30) > 4.48$. Of most interest is the interaction, which indicates that the renewal effect was stronger in Group ABC than in Group AAC. Finally, correlated t tests were performed contrasting the suppression in each group on Trial 1 of renewal testing in the extinction context and in Context C. The smallest $t(15) = 3.08$; thus, renewal was significant in each of the three groups.

A Group × Context ANOVA was also performed on the pre-CS rates from Trial 1 of the renewal tests. Of most interest, the effect of context did not approach significance, $F(1,45) = 1.29$, $p = .29$, meaning that the renewal effect described above was not complicated by differences in response rate when rats were tested in the extinction context or in Context C (Ms = 89 and 99 responses/min, respectively). Furthermore, the Group × Context interaction was also insignificant, $F(2,45) = 1.81$, $p = .18$.

Discussion

The main finding of Experiment 4 was that AAB (AAC) renewal, though significant, was significantly weaker than ABC renewal, which in turn was indistinguishable from ABA (CAC) renewal. These results rule out the hypothesis that AAB renewal is weak only because the test context differs from the acquisition context because that was true for both Groups AAC and ABC. We are left with the hypothesis that AAB renewal was weak because the extinction context was identical to the acquisition context.

General discussion

Experiment 1a demonstrated ABA renewal with just three features distinguishing Contexts A and B. Experiment 1b eliminated renewal by removing one of those features (an odor cue). Similarly, in Experiment 2, ABA renewal occurred again when only three features distinguished Contexts A and B, but was abolished by removing one or two of those features. Experiment 3a replicated the ABA renewal effect of Experiment 1a and found a weaker but significant AAB renewal effect under the same conditions. Experiment 3b added further distinctions to the A and B contexts but failed to enhance either ABA or AAB renewal. A methodological implication of these findings is that few salient differences between contexts are required to demonstrate renewal and that little seems to be gained by adding further distinctions. Experiment 4 replicated the AAB and ABA renewal of Experiment 3a and compared these effects with ABC renewal. ABA and ABC renewal were similar in magnitude, and both were stronger than AAB renewal.

The greater strength of ABA over AAB renewal has important implications for theories of renewal. As noted by Tamai and Nakajima (2000), the stronger ABA effect argues against the model of renewal proposed by Bouton and Ricker (1994). In that model, an excitatory association (a CS–US association) is formed during acquisition and is independent of its context. In extinction, an inhibitory association (a CS-no-US association) is formed that opposes the excitatory association, which itself remains fully intact. Unlike the excitatory association, the inhibitory association is modulated by its context. When the context is changed from extinction to test, the inhibitory link is removed, allowing the excitatory link to be manifest. This theory incorrectly predicts that ABA and AAB renewal should be equal in strength because each involves removal of the extinction context and because the generalization of

fear from A to B is expected to be just as strong as the generalization from A to A. For similar reasons, this view also incorrectly predicts that AAB and ABC renewal should be equal.

Another implication of the Bouton–Ricker model is that renewal should always be complete. If renewal reflects only the removal of an inhibitory link and if excitation is independent of context, then there can never be transfer of extinction from the extinction context to a different test context. The literature suggests, however, that renewal is seldom complete: there is almost always evidence for a transfer of extinction across contexts (e.g., Bouton & King, 1983, Fig. 1; Gunther et al., 1998, Fig. 1; Harris et al., 2000, Fig. 2; Rauhut et al., 2001, Figs. 1, 2, & 7; present report, Fig. 2). Often, the evidence for transfer of extinction takes the form of faster loss of responding during nonreinforced renewal test trials. On the first test trial, the CR of the ABA extinction group and the forgetting control group are often similar (e.g., Bouton & King, 1983, Fig. 1). This initial similarity could be taken to suggest that renewal was indeed complete on the first trial and that the subsequent faster loss of CR in the ABA group reflects some new process. Such a new process might be the phenomenon of "discriminated extinction," in which the absence of reinforcement comes to signal further nonreinforcement. After all, for Group ABA, the renewal test trials are a second extinction series, whereas for the forgetting control group, those same trials are only the first extinction series. Although a new process, such as discriminated extinction, may indeed contribute to the observed data pattern, a second, seemingly more parsimonious, interpretation of that pattern should be considered. That interpretation might hold that a ceiling effect obscures group differences on the first test trial. Subsequent nonreinforced test trials, by weakening conditioned suppression, remove the ceiling effect, allowing true group differences to become manifest (cf. Annau & Kamin, 1961, Fig. 2).

Part of the evidence for the Bouton–Ricker model's assumption that excitation is independent of context is a finding frequently reported in the Bouton laboratory. That is, CS-value acquired in Context A appears to transfer perfectly to Context B during extinction (e.g., Bouton & King, 1983; Bouton & Peck, 1989). Other workers, however, (e.g., Goddard, 1999; Hall & Honey, 1989, 1990) have found evidence for a loss of CS-value across contexts. The present studies have found both effects. There was little evidence for such a loss in Experiments 1a, 1b, 2, 3a, and 4, where the A and B contexts were distinguished in terms of only a few features, but there was strong evidence for a loss in Experiment 3b, where the A and B contexts were distinguished by many features. Some of those added features, though, were visual ones, and it is possible that these made the visual CS (lights off) appear different in the acquisition and extinction contexts. It is thus hard to know whether the weakening of suppression when the context was changed in Experiment 3b reflected generalization decrement across contexts or generalization decrement across CSs.

Less extreme than the Bouton–Ricker model is a theoretical position that Bouton has taken elsewhere (e.g., Bouton, 1993). On this view, excitation is again retained throughout extinction but is ultimately balanced by inhibition. Excitation and inhibition both generalize across contexts, and both show generalization decrement, but inhibition (or the second-learned association [Bouton & Nelson, 1998]) shows the

greater generalization decrement (cf. Pavlov, 1960, p. 99). By allowing inhibition to show some generalization across contexts, this view can explain the often-found transfer of extinction in ABA paradigms. By assuming inhibition to show more generalization decrement than excitation does, the view explains all forms of renewal, including ABA, AAB, and ABC renewal. By allowing excitation to show some generalization decrement across contexts, the view correctly predicts that ABA renewal should be stronger than AAB renewal. However, we think it makes this prediction for the wrong reason. In our Experiments 3a and 4, for example, ABA renewal was indeed stronger than AAB renewal, but, in Experiment 3a there was no evidence for imperfect transfer of excitation outside the acquisition context. In Experiment 4, there was, to be sure, a tendency toward imperfect transfer but it was small and did not reach significance despite the unusually large sample size involved in the comparison of appropriate groups ($n = 32$ in one group and 16 in the other). Given these facts, it is extremely difficult for the model to argue that AAB renewal was weaker than ABA renewal because of generalization decrement of fear from the acquisition context to the renewal test context in Group AAB. Furthermore, if such generalization decrement were cause of the weak AAB renewal, then ABC renewal should have also been quite weak relative to ABA renewal. That was not the case.

Weaker AAB renewal than ABA renewal in Experiment 3a and weaker AAB renewal than ABC renewal in Experiment 4 suggests a previously unconsidered process that reduces renewal when extinction occurs in the acquisition context. For example, the CS for Group AAB may actually lose excitatory value during its extinction in the A context (in addition to being merely opposed by growing inhibition). Then, when renewal is assessed in Context B, and the inhibition dissipates, the residual excitation may generalize perfectly to the test context, but there is less excitation to generalize. The consequence is that AAB renewal is weak.

Why should extinction in the A context particularly foster the loss of the CS's excitatory value? One plausible hypothesis is that Context A retains during the extinction of the CS some of the associative value it acquired when the CS was originally reinforced in its presence. Nonreinforcing a CS in an excitatory context causes it to lose more value than would nonreinforcing it in a less excitatory context (Rescorla & Wagner, 1972). This hypothesis is consistent with the findings of Rauhut et al. (2001) that renewal could be thwarted completely by explicitly unpaired, differential conditioning, and conditioned inhibition procedures. All three of these procedures ensure that the CS is nonreinforced in a background whose excitatory value is maintained throughout all of the CS extinction trials. An alternative possibility, however, is that the loss of CS-value would be greater in Context A than in Context B even if their associative values were equated. The present studies were not designed to test these possibilities.

Regardless of the proper theoretical interpretation of our results, the clinical implications are quite clear. There is indeed a therapeutic benefit to making the extinction context identical to the context in which fear was acquired (AAB renewal is weaker than both ABA and ABC renewal). This gives experimental support to the old adage about getting right back up on the horse after a fall. Often, however, this is not done, and when clients enter therapy, they cannot even describe the context in

which their fears were acquired (Loftus, 1993; Ost & Hugdahl, 1981, 1983). Fortunately, laboratory work with renewal paradigms has shown that, in such cases, it is not necessary to make the extinction context resemble the acquisition context. Even when the extinction and acquisition contexts are dissimilar, renewal can be thwarted by making the extinction context resemble the test context, as found by many investigations of the ABB case (e.g., Bouton & Bolles, 1979; Harris et al., 2000; Tamai & Nakajima, 2000; present report). Thus, therapies involving "assignments" in the client's home or workplace (e.g., Emmelkamp, 1982, Chapter 12) appear to have sound experimental support.

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