Spontaneous recovery from overexpectation

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In three Pavlovian magazine approach experiments, rats received conditioning of auditory and visual stimuli by pairing with a pellet. Then the stimuli received additional conditioning while presented in simultaneous compound and were tested either immediately or after a delay. The compound conditioning resulted in a decrement in responding to the individual stimuli (overexpectation). However, there was recovery of responding with the passage of time. These results suggest that the decrements produced by an overexpectation procedure share some properties with those produced by nonreinforcement.

A major conclusion from contemporary studies of Pavlovian conditioning is that conditioned stimuli (CSs) interact with each other as they develop associations with an unconditioned stimulus (US). One of the most striking demonstrations of this interaction is the phenomenon of overexpectation, in which the usual incrementing action of a US on a CS is reversed because of the contemporaneous presence of a second CS. In a standard demonstration of overexpectation (e.g., Khallad & Moore, 1996; Kremer, 1978; Rescorla, 1970; Wagner, 1971), two stimuli, A and B, are separately paired with a US until they achieve asymptotic conditioning. Then they are presented as an AB compound and the same reinforcement is continued. In many conditioning preparations, this joint presentation of A and B in compound results in greater responding than that produced by either stimulus alone—so-called summation (e.g., Mackintosh, 1974; Pavlov, 1927). Of particular interest, following the AB compound by the same US results in a decrease in subsequent responding to the A and B stimuli (e.g., Lattal & Nakajima, 1998; Rescorla, 1999).

This phenomenon was originally derived as a prediction from the Rescorla–Wagner (1972) model. According to that model, and to many other contemporary models of conditioning, changes in associative strength are governed by an error calculation in which the current associative strength of the CS compound (V_{AB}) is compared with the strength that the US is capable of producing (λ). Initial conditioning of A and B individually results in the separate associative strengths (V_A and V_B) each achieving levels near λ . However, presentation of the AB compound results in a combining of their associative strengths such that the total exceeds λ . As a result, the error calculation that occurs on a reinforced AB trial yields a negative result; that is, it produces a decrease in the associative strength of the elements. Casually put, the US is overexpected on the

compound trials, and since the effect of a US depends on its discrepancy from expectation, the result of a trial is associative decrement.

This sort of model views overexpectation as involving the same process as does extinction produced by nonreinforcement. In both cases, the trial consequent is lower than that anticipated on the basis of the stimuli present on the trial, resulting in a negative error term. In both cases, the result is a decrease in associative strength of the stimuli present on the trial.

The simplistic inference from such models that extinction results in a reversal of the action of conditioning has largely been discarded. Both classical and contemporary phenomena have led to this decision. For instance, Pavlov (1927) was the first to report that the decremental effects of extinction diminish with the passage of time, resulting in spontaneous recovery. This led him, and most subsequent thinkers, to conclude that at least a portion of the original associative learning had remained in place. A more contemporary finding, leading to the same conclusion, is that extinguished CSs continue to display associations with the US when given tests such as US-devaluation or US-dependent transfer (see, e.g., Rescorla, 1999). Findings such as these have led many to conclude that extinction involves not the removal of original learning but rather the superimposition of some contrary, perhaps US-independent, process that prevents performance.

However, the fact that such models are wrong in their identification of the mechanism underlying response decrement in extinction does not mean that they are wrong in seeing extinction and overexpectation as due to a common decremental process. In support of this possibility, Rescorla (1999) found that the decrement induced by overexpectation shared with that induced by extinction the continued ability of the CS to show US-specific transfer. Moreover, McNally, Pigg, and Weidemann (2004) and McNally and Westbrook (2003) have recently reported that in a fear conditioning preparation, naloxone attenuates the decrement induced by both overexpectation and extinction. However, there has been relatively little investigation of whether extinction and overexpectation share

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other features that might encourage the view that they are attributable to the same process.

The goal of the present study was to explore, for stimuli subjected to overexpectation, the possibility of another phenomenon that is commonly observed for stimuli given extinction, spontaneous recovery. This paper reports the results of three experiments that used two different procedures for producing overexpectation and three different techniques for detecting spontaneous recovery. All of the experiments used a Pavlovian magazine approach procedure with rat subjects. In this procedure, a diffuse auditory or visual stimulus signals the delivery of a pellet US in a food magazine. As a result of conditioning, the animal increasingly explores the magazine during presentation of the CS.

EXPERIMENT 1

This experiment had two intentions. The first was to provide a within-subjects documentation of the decremental effect of an overexpectation procedure in comparison with a control stimulus not given that procedure. The second was to examine whether or not that decrement was reduced with the passage of time. Figure 1 illustrates the design. The animals were first given Pavlovian conditioning of four stimuli, two visual (V_1 and V_2) and two auditory (A_1 and A_2) with a food pellet US. Then one auditory and one visual stimulus were presented in compound (A_1V_1) and followed by the same US. One of those stimuli was then tested immediately, as was the untreated stimulus of the same modality. After a week of no experimentation, the other pair of stimuli was given a similar test. The comparison of the two stimuli during the first test provided the opportunity to observe overexpectation; the second test provided a similar comparison after a lapse of time, possibly permitting recovery from the decremental effects of compound conditioning.

Method

Subjects and Apparatus

The subjects were 16 male Sprague–Dawley rats about 150 days old. They were housed in individual cages and placed on a food deprivation regime that kept them at 80% of their ad lib body weights for the course of the experiment. They had free access to water in their home cages.

The apparatus consisted of four operant chambers measuring $22.9 \times 20.3 \times 20.3$ cm, identical to those used in previous reports (e.g., Colwill & Rescorla, 1985). The two end walls of each chamber were made of aluminum; the sidewalls and ceiling, of clear Plexiglas. The floor of the chamber was composed of 0.48-cm stainless steel rods, spaced 1.9 cm apart, center to center. Each chamber had a recessed food magazine located behind a 4×4 cm opening in the center of one end wall. An infrared detector and emitter system was mounted on the side walls of the magazine, 1.5 cm behind the opening and 1.5 cm from the floor of the magazine, permitting automatic recording of head movements into the magazine.

Each chamber was enclosed in a sound- and light-resistant shell. Mounted on the inside wall of this shell were two speakers that permitted the presentation of a white noise (N) and an 1800-Hz tone (T), each measuring approximately 76 dB re $20 \mu\text{N/m}^2$ against a background level of 62 dB. Also mounted on that wall was a 6-W bulb that could be illuminated to provide a light (L) stimulus during

the otherwise dark session. Another 6-W light, mounted on the ceiling of the chamber, could be flashed on at a rate of 1/sec to produce a flashing (F) stimulus. A food dispenser containing 45-mg pellets (P. J. Noyes, Formula A) allowed delivery of pellets into the food magazine.

Experimental events were controlled and recorded automatically by relays and microprocessors located in an adjoining room.

Procedure

Magazine training. On the 1st day, the animals received a 20-min magazine training session, during which 20 noncontingent deliveries of pellets were given, at time intervals variable around a mean of 1 min.

Conditioning. On each of the next 10 days, all animals received Pavlovian conditioning of each of the four stimuli. Each day the animals received eight 30-sec presentations of each stimulus, terminating in the delivery of a food pellet. The stimuli were presented in a balanced order, with the constraint that no more than two trials of the same type could occur consecutively. The intertrial interval (ITI), defined from trial onset to trial onset, was variable around a mean of 2.5 min in these and all subsequent sessions. The number of photo beam interruptions by head entry into the magazine was recorded during presentation of each 30-sec stimulus and during the 30-sec stimulus-free period preceding each trial.

Overexpectation. On each of the next 3 days, all animals received conditioning with a compound of two stimuli, one auditory and one visual. Each trial consisted of a 30-sec presentation of a simultaneous compound terminating in a pellet. On Days 1 and 2, there were 16 trials; on Day 3, there were 8 trials. Four different groups of animals received the four different possible auditory/visual compounds.

Test 1. Approximately 1 h after the third overexpectation session, half of the animals received a test session consisting of four non-reinforced counterbalanced 30-sec presentations of both auditory stimuli; the other half of the animals received similar presentations of both visual stimuli. Assignment to test stimuli was arranged to be orthogonal to the preceding treatments.

Test 2. After a week, which the animals spent on their deprivation schedules in their home cages, they all received a second test session identical to the first, except that the stimuli of the other modality were used.

Results and Discussion

Initial acquisition proceeded smoothly. On the final day, the mean responses per minute ranged from 17.4 to 18.6

Cond	Over	Test 1	Rest	Test 2
A_1+	A_1V_1+	A_1		V_1
V_1+		A_2		V_2
A_2+		V_1		A_1
V_2+		V_2		A_2

Figure 1. Design of Experiment 1. After conditioning of two auditory (A_1 and A_2) and two visual (V_1 and V_2) stimuli with a pellet (+), one compound was separately given overexpectation (Over). Then there was a test of both auditory and both visual stimuli, either immediately or after a delay.

across the different stimuli, with no reliable differences. The mean responses per minute during the 30 sec prior to the stimuli was 6.2. The initial response to the compounds was slightly but not reliably greater than that to the elements. On the 1st day of compound training, the mean responses per minute were 19.1 and 5.9 during the stimulus and prestimulus periods, respectively. Responding dropped slightly, but not reliably, to 18.6 and 6.1 responses per minute, respectively, on the final day of compound training. Although summation of responding is routinely observed in this preparation (see, e.g., Rescorla, 1999), it can be difficult to see in comparisons involving different stimuli presented in different sessions or portions of sessions (e.g., Lattal & Nakajima, 1998). As in earlier experiments using this procedure to study overexpectation, the rates of responding remained stable over the course of compound conditioning. It seems possible that the high level of responding to the compound in this experiment represented a response ceiling.

Figure 2 displays the mean responses per min during the two test sessions, one given immediately after overexpectation and one a week later. Because there were no reliable within-test differences in the rates of responding prior to the stimuli, those data have been combined. During the first test session, both stimuli continued to elevate responding in comparison with the prestimulus rate. However, responding was reliably higher for the control stimulus than for the stimulus given compound conditioning [Wilcoxon $T(14) = 11$, $p < .01$]. That difference documents the decremental effect of the compound training and replicates earlier findings of overexpectation in this preparation (e.g., Lattal & Nakajima, 1998; Rescorla, 1999). By contrast, during the second test, shown in the right panel, there was no difference in responding to the two stimuli. Comparison between the two tests indicates that the difference between responding to the control and

treated stimuli was greater in the first test [$T(14) = 19$, $p < .05$]. That observation suggests that the depressive effects of compound conditioning had declined with the passage of time—that is, that spontaneous recovery from overexpectation was observed.

It is worth noting that the control and treated stimuli differed not only in whether or not they were presented in compound but also in whether or not they received additional conditioning. As Lattal and Nakajima (1998) pointed out, an alternative account of many overexpectation experiments is that the additional conditioning produces inhibition of delay in which there is loss of responding during the initial part of the stimulus. Although the control treatment used in the present experiment does not speak to this possibility, Lattal and Nakajima, using procedures very like those used here, found no evidence that inhibition of delay accounted for the decremental effects of compound conditioning.

EXPERIMENT 2

Experiment 1 used a standard spontaneous recovery design in which a decremental treatment was conducted and then the animal was tested either immediately or after a time delay. As Rescorla (2004) has noted, this is only one of several possible spontaneous recovery designs. Moreover, it has the disadvantage of implicitly comparing responding at two different times, when the animal may be in two quite different overall states. Indeed, inspection of Figure 2 reveals that there was a somewhat lower level of performance in Test 2 than in Test 1 for the control stimulus and the prestimulus responding. Although this difference did not prove to be reliable, it does suggest caution in the comparison of performance across two different tests.

In order to avoid the need for such a cross-session comparison, Rescorla (2004) has suggested an alternative procedure for assessing spontaneous recovery. Experiment 2 adapted that procedure to the study of recovery from overexpectation, as illustrated in Figure 3. Rats initially received conditioning with two auditory stimuli, A_1 and A_2 , and two visual stimuli, V_1 and V_2 . Then they received reinforcement of two mixed modality compounds, A_1V_1 and A_2V_2 , followed by a test of the two auditory stimuli. However, the conditioning of the A_1V_1 compound took place at a temporal distance from the test, whereas that of the A_2V_2 compound took place immediately before the test. The result is that A_1 had an opportunity to recover from the decremental effects of the compound trials whereas A_2 had not. That is, A_1 might be expected to show spontaneous recovery relative to A_2 .

This mode of testing spontaneous recovery had the advantage of allowing a comparison between two stimuli differing in their times since decremental treatment but sharing the time of their test session and the time since initial conditioning. As Rescorla (2004) has noted in applying this procedure to spontaneous recovery after extinction, this shared time of test offers advantages over the conventional procedure in ruling out interpretations in terms of changes in the animal with time. The primary question was whether

Figure 2. Results of the two test sessions in Experiment 1. Mean responses per minute are shown for individual test trials in the prestimulus period (Pre) and during the stimulus given compound training (Over) or not (Cont).

Cond	Over 1	Rest	Over 2	Test
A ₁ +	A ₁ V ₁ +			A ₁
V ₁ +				
A ₂ +				
V ₂ +			A ₂ V ₂ +	A ₂

Figure 3. Design of Experiment 2. After conditioning of two auditory (A₁ and A₂) and two visual (V₁ and V₂) stimuli with a pellet (+), two different auditory/visual compounds were given overexpectation treatment, and then the auditory stimuli were tested.

there would be greater responding to A₁ than to A₂, suggesting recovery of responding with time.

Method

Subjects and Apparatus

The subjects were 16 male Sprague–Dawley rats of the same type and maintained in the same manner as in Experiment 1. The apparatus consisted of eight operant chambers identical in all essentials with the chambers used in Experiment 1, except that the flashing light was mounted outside the rear of the chamber at grid level.

Procedure

Magazine training. On the 1st day, the animals received a 20-min magazine training session, during which 20 noncontingent deliveries of pellets were given, at time intervals variable around a mean of 1 min.

Conditioning. On each of the next 8 days, all animals received Pavlovian conditioning of each of the four stimuli, identical to that used in Experiment 1. Each day the animals received eight 30-sec presentations of each stimulus, terminating in the delivery of a food pellet.

Overexpectation Phase 1. On each of the next 3 days, all animals received conditioning with a compound of two stimuli, one auditory and one visual. Each trial consisted of a 30-sec presentation of a simultaneous compound terminating in a pellet. On Days 1 and 2, there were 16 trials; on Day 3, there were 8 trials. Four different groups of animals received the four different possible auditory/visual compounds.

Overexpectation Phase 2 and test. After a 5-day rest, during which the animals remained on a deprivation schedule in their home cages, the animals received the same treatment with the other auditory/visual compound. The third compound conditioning session continued without interruption with a test. During that test, each auditory stimulus was presented four times without reinforcement, in counterbalanced order.

Results and Discussion

Initial conditioning was uneventful. The terminal levels of responding for the auditory stimuli on the final day of conditioning are shown at the left of Figure 4, separated according to whether these stimuli would be subjected to overexpectation and then tested immediately or with a delay. There were no reliable differences between these stimuli or as a function of stimulus identification. The mean levels of responding during the first and second compound stages were 15.0 and 15.8, respectively. These numbers were only slightly, and not reliably, greater than the levels of responding to the individual stimuli at the end of training. The rates of responding remained stable over the course of compound conditioning.

The right side of Figure 4 shows the results of the final test session. Responding rapidly extinguished over the course of the test, but the overall level of responding was more substantial for the stimulus given a delayed test [$T(16) = 27.5, p < .05$]. The stimulus tested immediately began testing at a level of responding lower than that it had attained at the end of training, and its level continued to be lower throughout the test. These results suggest that there is recovery from overexpectation with time.

Although a within-subjects version of this particular design for studying spontaneous recovery has substantial advantages, it does not allow comparison with stimuli not given compound training, unless many more than four stimuli are available for use. However, it does yield a comparison of two different stimuli, both given treatment and tested in the same session, but with different opportunities for recovery. Consequently, this experiment provides support for the conclusions of Experiment 1, using a different procedure for assessing recovery.

EXPERIMENT 3

Although Experiments 1 and 2 showed some evidence of recovery from overexpectation, the magnitude of this recovery was constrained by the magnitude of the decremental effects of the overexpectation treatment. The decrement from overexpectation may have been limited by several features of these experiments. First, the compound phase involved only a few reinforced trials, 40 spread over 3 days. Second, the decremental impact of reinforcing an AB trial was shared between the A and B stimuli, reducing the amount forced on any one stimulus.

The goal of Experiment 3 was to strengthen the decremental effect by modifying both of these features of Experiments 1 and 2. First, the number of reinforced compound trials was increased to 96, spread over 6 days. Second,

Figure 4. Mean responses per minute at the end of training and during the test session of Experiment 2. Responding is shown during the prestimulus period (Pre) and then for the auditory stimulus tested immediately and with a delay after its compound treatment.

separate reinforced presentations of A were added to the AB+ trials. According to most error correction models, these separate A+ trials should maintain the strength of A, thereby forcing B to account for all of the decrement that occurred on AB+ trials. Of course, this manipulation constituted a variation on a blocking experiment (e.g., Wagner, 1969); however, unlike blocking experiments in which B is initially neutral, the present experiment applied the A+/AB+ procedure to a previously well-conditioned B. The expectation was that this treatment should depress an already excitatory stimulus. These enhancements of the decremental effects of overexpectation should then provide more leeway for recovery with time.

The design is sketched in Figure 5. After initial conditioning of V_1 , V_2 , A_1 , A_2 , each animal received reinforcement of one of the auditory stimuli in compound with each of the visual stimuli. Each of six sessions contained eight reinforced presentations each of V_1 and V_2 separately, together with eight reinforced presentations of either A_1 or A_2 in compound with V_1 and with V_2 . The intention was to use separate reinforced presentations of V_1 and V_2 to force the decremental impact on the compound to reside largely in the auditory stimulus. Both V_1 and V_2 were used in compound with the auditory stimulus in order to reduce the contribution of any cues unique to a particular compound. If a particular compound-unique cue were always present on compound trials, it could absorb some of the decrement, thereby reducing the decrement attributed to the auditory stimulus itself.

In order to provide an assessment of the decremental impact, a brief test session was given with A_1 and A_2 immediately after the final session of compound training. In order to assess recovery, an identical test was given a week later. Although Rescorla (2004) has criticized this design for studying spontaneous recovery because it involves assessing recovery in a stimulus that has had a previous immediate test, it is the procedure most frequently used in the literature. In order to reduce the confounding effects of the

previous test, the primary comparison was that between control and treated stimulus within the second test.

Method

Subjects and Apparatus

The subjects were 16 male rats of the same sort and maintained in the same manner as in Experiment 1. The apparatus was that of Experiment 1.

Procedure

Initial conditioning. Following magazine training identical to that used in Experiment 1, all animals received Pavlovian conditioning of all four stimuli: noise, clicker, light, and flash. Each of 10 sessions contained eight reinforced 30-sec presentations of each stimulus, given at a mean ITI of 2.5 min. The order of trials was balanced, with the constraint that no more than two trials of any type could be given consecutively.

Overexpectation. Over the next 6 days, the animals received compound training of one of the auditory stimuli presented in conjunction with each of the visual stimuli. Each day contained eight reinforced presentations each of L and F, intermixed with eight reinforced presentations each of L and F in compound with either T or N. The other auditory stimulus was not presented.

Tests. About a hour after the final day of overexpectation training, the animals received a test session with both N and T. This test began with two reinforced presentations each of L and F and continued with two nonreinforced presentations of T and N, with a mean ITI of 2.5 min. After a week spent in their home cages on a continued deprivation schedule, the animals were returned to the experimental chambers for a second test, identical to the first.

Results and Discussion

The results of initial conditioning were similar to those in the previous experiments. On the final conditioning day, the mean responses per minute were 5.6, 16.6, and 16.2 for the prestimulus period, the auditory stimuli, and the visual stimuli, respectively. There were no reliable differences either between or within stimulus modality. On the first day of overexpectation training, the mean responses per minute were 6.9, 14.4, and 18.4 for the prestimulus period, the visual stimuli, and the compound, respectively. The superior responding during the compound, compared with that during the visual stimulus alone, was highly reliable [$T(16) = 1, p < .01$]. On the final day of compound training, the comparable numbers were 5.8, 15.8, and 18.5. The difference between element and compound trials remained reliable [$T(16) = 9, p < .01$]. These results provide within-session evidence of summation consistent with earlier findings from this preparation (see, e.g., Rescorla, 1999).

The results of most interest, from the tests, are shown in Figure 6. The figure displays the levels of responding to the control and treated stimuli at the end of acquisition, during the first test immediately after overexpectation, and then during the second test a week later. It is clear that in the first test there was substantially more responding to the control stimulus than to the stimulus subjected to overexpectation [$T(16) = 18, p < .01$]. It is particularly worth noting that the application of the A+, AB+ procedure did not simply produce blocking of B, but actively depressed previously established conditioning. By contrast, in the second test there was relatively little difference

Cond	Over	Test 1	Rest	Test 2
A_1+	V_1+			
V_1+	V_2+	A_1		A_1
A_2+	A_1V_1+	A_2		A_2
V_2+	A_1V_2+			

Figure 5. Design of Experiment 3. After conditioning of two auditory (A_1 and A_2) and two visual (V_1 and V_2) stimuli with a pellet (+), one of the auditory stimuli was presented in compound with both V_1 and V_2 , mixed with separate reinforced presentations of V_1 and V_2 alone. Then A_1 and A_2 were tested immediately and after a delay.

Figure 6. Mean responses per minute at the end of training and during the two test sessions of Experiment 3. Responding is shown during the prestimulus period (Pre) and then for the control stimulus and the stimulus given overexpectation treatment in tests given immediately (Test 1) and after a delay (Test 2).

between the two stimuli [$T(16) = 55$, n.s.]. Although there are reasons to be suspicious of the conventional comparison between tests, the difference observed on Test 1 was reliably greater than that observed on Test 2 [$T(15) = 25$, $p < .05$].

These results confirm and strengthen those of Experiments 1 and 2. The auditory stimulus tested immediately after the application of a V+, VA+ procedure promoted a markedly lower level of responding than did a control stimulus. However, with the passage of a week's time, the difference disappeared, suggesting substantial spontaneous recovery from the decremental effects of overexpectation.

It is worth noting that although the decrement produced in this experiment by the overexpectation procedures was substantial, it was far from complete. It was certainly short of the decrement that would have been produced by a comparable number of nonreinforced trials. However, this incompleteness may reflect a limitation not on the overexpectation mechanism but on the manner in which it is assessed. An overexpectation procedure necessarily involves application of the decremental process in the context of another stimulus, but then that decrement is assessed when the stimulus is presented alone. It is well documented that such a change of contexts will lead to substantial renewal of responding in the case of extinction (see, e.g., Bouton & Ricker, 1994). It seems possible that a similar renewal effect leads to elevated responding in both the immediate and delayed tests with an overexpectation procedure.

GENERAL DISCUSSION

These experiments provide evidence for the recovery with time from the decremental effects produced by reinforcing a stimulus compound. They used two different overexpectation paradigms and three different procedures

for assessing recovery. This finding of spontaneous recovery in each case is consistent with the possibility that the mechanism underlying the decremental effects of overexpectation is similar to that underlying the decremental effects of extinction. This agrees with the inference commonly drawn from contemporary error correction models.

These findings are also consistent with the results of two other procedures that produce changes after initial conditioning. In a recent series of experiments, Rescorla (1997) studied the associative changes produced by replacing one rewarding stimulus with another. Using a magazine approach, he found that replacing a pellet reward with a similarly valued, but qualitatively different, sucrose reward left the original association with the pellet in place while simultaneously superimposing association with the sucrose. Yet this additional association did not result in an increase in the level of performance. He suggested that this was because the procedure effectively involved overexpectation, which allowed both associations to remain in place but also yielded an outcome-independent depressive process like that of extinction. Consistent with this claim, he found that allowing for the passage of time after such sequential training with two outcomes resulted in a spontaneous increase in responding, as though there had been a loss of a portion of the decremental process with time (see, e.g., Rescorla, 1997).

The observation of spontaneous recovery after overexpectation is also consistent with the observation of spontaneous recovery after an extinction procedure that makes the CS irrelevant to the delivery of the US. For instance Tomie, Hayden, and Biehl (1980), using sign tracking in pigeons, found that the decrement in performance produced by a shift from contingent to noncontingent US delivery dissipated with the passage of time. Many contemporary interpretations of noncontingent US delivery view it as concurrently conditioning both the CS and the background, with the result that any previous conditioning to the CS is depressed by the introduction of USs in the background alone (e.g., Rescorla & Wagner, 1972). The mechanism that Rescorla and Wagner describe for that depression is the same as that for overexpectation, an inappropriately high negative error term on the background plus CS trials. Consequently, the recovery from a noncontingent procedure would be anticipated on the basis of the present observation that there is recovery from overexpectation.

One may view the present instances of temporally induced recovery from overexpectation in the context of two other literatures. First, there is at least one other instance of recovery from expectation induced not by time but by an experimental manipulation. Blaisdell, Denniston, and Miller (2001) found that subsequent extinction of one member of a compound previously given overexpectation training resulted in increased responding to the other member. Second, there are other instances of recovery from decremental procedures with the passage of time. For instance, Kraemer, Lariviere, and Spear (1988) and Pineño, Urushihara, and Miller (2005) have reported that with the passage of time there is recovery from the adverse effects of overshadowing and blocking, respec-

tively. Those results differ from the present ones in that overexpectation involves the depression of a previously well-conditioned stimulus, rather than the attenuation of initial conditioning. However, it is possible that related mechanisms are involved.

Although the present results speak most directly to the circumstances that produce decrement, they may also have implications for the content of what is learned. To the degree that the AB+ and A+, AB+ procedures produce decrement with the same properties as that produced by nonreinforcement, these findings suggest that the same process may be involved. It is common to appeal to the development of an association of the CS with the "noUS" as an account of extinction. However, the present procedures produce decrement despite the continued occurrence of the US itself. This suggests that an extinction-like decrement can be produced under conditionings where appeal to the learning about the "noUS" is not plausible. It suggests that the decrement depends not on the absolute value of the trial ending event, but rather on its value relative to that anticipated on the basis of the CS.

That inference about relative anticipation fits with the results of other extinction experiments. For instance, the degree to which a nonreinforcement produced decrement can be modulated by the associative strength of concurrently present stimuli. The concurrent presence of an excitor can amplify the decremental effect of nonreinforcement (Rescorla, 2000; Wagner, 1969), whereas the concurrent presence of an inhibitor can reduce its effect (Rescorla, 2003; Soltysik, Wolfe, Nicholas, Wilson, & Garcia-Sanchez, 1983). The same "noUS" apparently can have varying decremental effects, depending on the strength of the US anticipated.

In accord with this conclusion is the observation that the application of extinction and overexpectation procedures does not reduce the net strength of associations with the US. For instance, Rescorla (1996) found that although extinction did diminish responding, it did not decrease sensitivity to subsequent devaluation of the US. Similarly, the response decrease produced by overexpectation does not diminish the ability of stimuli to transfer control to instrumental responses with which they share a reinforcer. Rescorla (1993) has argued that this pattern of results could be accommodated if extinction and overexpectation produce interfering associations at the level of the response, rather than the reinforcer.

In this regard, it is worth noting that not all instances of applying an overexpectation procedure result in response decrement. Using a sign-tracking procedure in pigeons, Rescorla (1989) found little evidence for either summation or overexpectation. One possibility is that the failure to find response enhancement in summation prevented reinforcement from having a decremental effect, implying that overexpectation also involves some level of learning about the response rather than the reinforcer.

Regardless of the underlying mechanism, results such as these suggest that the phenomenon of extinction may be more general than is normally inferred from the use of simple nonreinforcement as an extinction procedure. The

present experiments encourage the placement of extinction in a broader context of a variety of decremental procedures. They suggest that investigation of such procedures may provide new insights into the nature of extinction itself.

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