Spontaneous recovery after Pavlovian conditioning with multiple outcomes

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In four experiments using rats, a Pavlovian conditioned stimulus (CS) was paired with a positive outcome, either pellets or liquid sucrose. That outcome was then either omitted altogether or replaced by another outcome. Although performance to the CS deteriorated only when the outcome was omitted, both procedures resulted in the CS's ability to evoke greater responding after the passage of time. These results suggest that a similar outcome-independent depressive process develops when a Pavlovian CS is paired either with nonreinforcement or with a different outcome; that process then appears to dissipate with time.

Spontaneous recovery of responding to an extinguished conditioned stimulus (CS) is one of the oldest and most pervasive observations in Pavlovian conditioning. It has been widely interpreted as suggesting that the associations originally learned when an unconditioned stimulus (US) follows a CS are left at least partially intact through the separate CS presentation in extinction. Consequently, it has motivated the search for some process other than destruction of those associations that might be responsible for the decrement in performance observed with extinction.

The present experiments were directed at the possibility of finding an analogous result when an originally trained association is subjected to another potentially destructive manipulation, pairing with an alternative US. When a stimulus (S) is first followed by one outcome (O1) and then by another (O2), one may view the S-O2 trials as potentially extinguishing the S-O1 association. The S is repeatedly presented in the absence of O1, albeit with the alternative outcome O2. If this view is correct, then one might anticipate seeing spontaneous recovery of the effects of the original S-O1 association if time passes after the S-O2 pairings. Such an observation is of considerable interest because it would imply that an extinction-like process is embedded in procedures using multiple outcomes.

There is some evidence to support this inference in the case in which O1 and O2 are quite different in valence. For instance, Bouton and Peck (1992) used a positive outcome (food) and a negative outcome (electric shock) in the roles of O1 and O2. Stimuli paired with those outcomes evoke distinctive behaviors, such as magazine approach and freezing, respectively. Bouton and Peck found that although the behaviors originally established by pairing with O1 deteriorated with the counterconditioning by O2, those behaviors recovered with the subsequent pas-

sage of time. They interpreted these findings as indicating that the pairing with O2 left the original S-O1 associations at least partially intact.

The experiments reported here used a similar procedure except that the two outcomes employed as O1 and O2 were a solid pellet and liquid sucrose. Other experiments have shown that these two outcomes, although similar in valence, are otherwise highly distinctive. When paired with a stimulus, they establish similar levels of the same behavior, magazine approach. Moreover, after performance is asymptotic, the replacement of O1 by O2 yields little change in response rate. Despite that, recent results (e.g., Delamater, 1996; Rescorla, 1996a) suggest that a stimulus trained first with O1 and then with O2 retains both the S-O1 and the S-O2 association, as detected by devaluation and transfer techniques. The fact that substituting O2 for O1 establishes an S-O2 association and also allows preservation of the S-O1 association, and yet does not result in augmented performance, suggests the possibility that some other process is depressing performance during the S-O2 training. If this process is like that observed in extinction, then one might observe spontaneous recovery of behavior following the passage of time after S-O2 training, despite the fact that this training did not itself lower performance.

When this sort of logic was explored in an analogous instrumental learning situation, evidence was indeed found for such recovery. Rescorla (1996b) first reinforced an instrumental response (R) with O1 and then with O2. As in the case of Pavlovian conditioning, prior experiments had suggested that this would result in the formation of both R-O1 and R-O2 associations (e.g., Rescorla, 1991, 1995). However, the training with O2 did not result in an overall increase in the rate of R. But, with the passage of time after that training, an increase did occur in R, in a manner analogous to spontaneous recovery.

Four Pavlovian experiments are reported here, all measuring a magazine-approach response in rat subjects. Experiment 1 documented spontaneous recovery following extinction in this preparation, using a within-subject de-

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sign somewhat different from that conventionally employed. Experiment 2 repeated Experiment 1, but using another outcome, O2, instead of nonreinforcement. Experiment 3 replicated the results of Experiment 2, providing some additional controls. Experiment 4 further replicated the results of Experiment 2, using a more conventional recovery design.

EXPERIMENT 1

The intention of Experiment 1 was to demonstrate spontaneous recovery following extinction in the present preparation. In a standard spontaneous recovery procedure, a stimulus is paired with an outcome, extinguished, and then tested after the passage of some period of time. The inference of spontaneous recovery is made when responding is greater following the waiting period than it was at the end of extinction. Unfortunately, this means comparing responding under conditions that differ in a variety of ways other than in the time since extinction. For instance, there are differences in the time since original training, in date of testing (with consequent differences of the overall age of the animals and length of time on deprivation), and in the number of previous extinction exposures (because the last observation at the end of extinction involves an additional extinction trial). In an attempt to reduce such confoundings, the present experiment adopted a somewhat different design, as illustrated in Figure 1.

Each rat was trained with two stimuli, S1 and S2, each resulting in either pellets or sucrose, O1 or O2. Although the design of the experiment did not require two different outcomes, they were used to minimize generalization and to provide comparability with subsequent experiments. Extinction was then given either immediately after training (for S1) or after a delay (for S2). Both stimuli were then tested for recovery immediately after the extinction of S2. This procedure of testing both stimuli at the same time allows one to compare recovery in two stimuli that differ in the time since their extinction while sharing the same time since training. It also controls for any general changes in the animal or overall responding with the passage of time.

Method

Subjects and Apparatus

The subjects were 16 male Sprague-Dawley rats about 90 days old. They were housed in individual cages and maintained on a

food-deprivation regime that kept them at 80% of their ad-lib body weight. They had free access to water in the home cage.

The apparatus consisted of four 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 aluminum; the side walls and ceiling were clear Plexiglas. The floor of the chamber was composed of 0.48-cm stainless steel rods, spaced 1.9 cm apart. Each chamber had a recessed food magazine in the center of one end wall. Two small metal cups, measuring 1.25 cm in diameter and 1.5 cm deep, were sunk side by side in the floor of each food magazine. An infrared detector and emitter system were mounted on the side walls 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 was a speaker that permitted the presentation of a white noise (N), measuring approximately 76 dB re 20 $\mu\text{N}/\text{m}^2$ 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. The outside ceiling of the shell supported a solenoid-operated gravity feed valve that was connected via plastic tubing to the left cup in the food magazine. This system permitted the presentation of 0.3 ml of an 8% sucrose solution. Also attached to that food magazine was a dispenser containing 45-mg pellets (P. J. Noyes Co., Formula A).

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

Procedure

Magazine training. On each of the first 2 days, the animals received a 20-min magazine training session. During the first session, there were 20 noncontingent deliveries of pellets; during the second session, there were 20 noncontingent deliveries of sucrose.

Pavlovian conditioning. On each of the next 12 days, all animals received Pavlovian conditioning of both N and L. Each session contained eight 30-sec presentations of each stimulus. For half of the animals, each N terminated in the delivery of a pellet and each L terminated in the delivery of sucrose. For the other half of the animals, the outcomes were interchanged. The intertrial interval (ITI), measured as the time between stimulus initiations, was variable around a mean of 90 sec. The number of head entries into the magazine was recorded during each 30-sec CS and during the 30-sec stimulus-free period preceding each CS.

Extinction Phase 1. On each of the next 2 days, the animals received nonreinforced exposure to either L or N, in a manner counterbalanced with the prior treatments. Each session proceeded like the conditioning sessions except that all 16 stimulus presentations were of the same stimulus and no outcomes were delivered.

Rest. No experimental treatments were administered for the next 6 days. The animals remained in their home cages and were maintained on their deprivation schedule.

Extinction Phase 2. On each of the next 2 days, the animals received extinction with the alternative stimulus. Sessions were exactly like those of Extinction Phase 1 except that the other stimulus was delivered for each animal.

Test. A test was administered without interruption at the end of the 2nd day of Extinction Phase 2. Each animal received four nonreinforced 30-sec presentations of L and N. The results of interest are the magazine entries during the stimuli as a function of whether they had received extinction immediately prior to or 8 days before the test.

Results and Discussion

Pavlovian conditioning of magazine entry proceeded smoothly. By the final day of initial training with pellets and sucrose, the mean entries per minute were 4.6 and 15.6 during the pre-CS and CS periods, respectively. There

Training	Ext1	Rest	Ext2	Test
S1-O1	S1-			S1
S2-O2			S2-	S2

Figure 1. Design of Experiment 1. Two stimuli (S1 and S2) were paired with different outcomes (O1 and O2). Both were then given extinction either at a distance (S1) or immediately before (S2) a test of both stimuli.

were no systematic differences as a function of CS or outcome identity.

Over the course of extinction, performance dropped rapidly to means of 1.2 and 1.4 during the pre-CS and CS periods on the last four trials of Extinction Phase 1 and 0.8 and 1.0 for the comparable periods in Extinction Phase 2. Although there was somewhat greater responding during Extinction Phase 1, it proved nonreliable.

Figure 2 shows the results from the final half-session of extinction and for the recovery test session, plotted for individual trials. It is clear that there was spontaneous recovery to the stimulus that had been nonreinforced 8 days earlier during Extinction Phase 1, but not for the stimulus that received extinction just prior to the test. The greater responding to the former stimulus was most evident on Trial 1 [Wilcoxon $T(9) = 0, p < .01$] but was also present for the session as a whole [$T(13) = 6.5, p < .05$]. This greater responding to the stimulus more removed in time from extinction constitutes a demonstration of spontaneous recovery.

EXPERIMENT 2

Experiment 2 examined the possibility of spontaneous recovery following a decremental treatment involving the substitution of one outcome for another. It was modeled closely on Experiment 1 except that a second outcome was substituted for nonreinforcement. Rats first received Pavlovian training with two different stimuli leading to unique outcomes. Each stimulus then received training with the alternative outcome, one before and one after a 6-day delay. Finally, both stimuli were tested for recovery.

Method

Subjects and Apparatus

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

like that of Experiment 1 except that eight, rather than four, chambers were used.

Procedure

Pavlovian conditioning. The animals received initial magazine training with pellets and sucrose, as in Experiment 1. They then received Pavlovian conditioning on each of 12 days, as in Experiment 1. Each session contained eight 30-sec presentations each of L and N. For half of the animals, L terminated in pellets and N terminated in sucrose; for the other half of the animals, the outcomes were interchanged.

Second Outcome Phase 1. On each of the next 2 days, the animals received 16 presentations of either L or N, counterbalanced across the conditioning treatment. In each case, the stimulus was followed by the outcome different from that used in conditioning. This phase lasted 2 days.

Rest. On each of the next 6 days, the animals remained in their home cages and were maintained on their deprivation schedule.

Second Outcome Phase 2. As in Experiment 1, Second Outcome Phase 2 was identical to the earlier phase of second outcome training except that the alternative stimulus was given, with its alternative outcome. This phase also lasted 2 days.

Test. The test was administered in a manner identical to that of Experiment 1. Four nonreinforced presentations each of L and N were added onto the end of the 2nd day of Outcome Training 2.

Results and Discussion

Pavlovian conditioning of magazine entry proceeded smoothly. By the final day of initial training with pellets and sucrose, the mean entries per minute were 6.8 and 20.8 during the pre-CS and CS periods, respectively. There were no systematic differences as a function of CS or outcome identity.

Over the course of the second outcome training phases, performance remained at approximately the same level, with means of 6.0 and 20.6 during the pre-CS and CS periods on the 2nd day of Second Outcome Training Phase 1 and 7.4 and 19.8 for the comparable periods in Second Outcome Training Phase 2. None of the differences between the two phases were reliable.

Figure 2. Results of Experiment 1. Magazine approach is shown to the stimulus extinguished at a temporal distance (S1) or immediately before (S2) the test. Responding is shown at the end of extinction and over the course of the test during each stimulus and during a prestimulus period.

The data of most interest, from the final test, are shown in Figure 3. This figure shows responding for the final half-session of training with the second outcome and over the course of the test. Responding was greater to the stimulus treated 8 days prior to the test than to that treated immediately prior to the test both on the initial test trial [$T(16) = 9, p < .01$] and for the test as a whole [$T(16) = 26, p < .05$]. The stimulus treated 8 days earlier also showed greater responding on the first test trial than at the end of its treatment [$T(16) = 20, p < .01$], whereas the stimulus treated immediately prior to the test did not.

These results suggest that a spontaneous-recovery-like phenomenon occurs when a stimulus is subjected to training with an alternative outcome instead of being extinguished. With the passage of time, there was an increase in responding that was not present either during or immediately after training with the second outcome. This suggests the possibility that a decremental process that functions during conventional extinction also functions during training with an alternative outcome, producing temporary depression from which there is recovery.

EXPERIMENT 3

The intention of Experiment 3 was to provide a replication of the result of Experiment 2 while evaluating an alternative interpretation. Our interpretation of Experiment 2 is that pairing of S with O2 results both in an S-O2 association and in some temporary depressive process from which there is recovery. According to this view, the delivery of S without O1 leads to the same depressive process as would occur in simple extinction; however, the occurrence of O2 leads to a superimposed S-O2 association that prevents performance decrement. It is critical to this interpretation that the outcome used in the second phase of training be different from that used in original training.

On the other hand, one might adopt a much simpler view according to which the recent presentation of a stimulus results in some short-term decremental process that temporarily reduces performance to that stimulus. A related idea, that of fatigue or reactive inhibition, has been discussed for the temporary decrements, and recovery from them, in the case of instrumental responding (Rescorla, 1996b). This view contrasts with that described above in making no reference to the identity of the outcome employed in the extinction phase. That is, it anticipates the same result even if Experiment 2 were repeated with the same outcome following S1 during original conditioning and during subsequent training.

In any case, it seems valuable to examine the importance of the identity of the outcome in Phase 2. Finding that the outcome matters would strongly constrain the interpretation of this result. Consequently, in Experiment 3, two groups of animals received conditioning like that used in Experiment 2. However, for one group, Phase 2 contained the same outcomes as used in original conditioning, whereas, for the other group, the outcomes differed, as they had in Experiment 2.

The design is schematized in Figure 4. Both groups of animals received Pavlovian conditioning of S1 and S2 using O1 and O2 as the outcomes. Both groups then received additional training, with S1 immediately and with S2 after a delay. Both groups then were tested with both stimuli. For Group S, each stimulus was paired with the same outcome throughout its various phases. For Group D, each stimulus was paired with two different outcomes.

Method

Subjects and Apparatus

The subjects were 16 naive male rats of the same sort and maintained in the same manner as in Experiment 1. The apparatus was that of Experiment 2.

Figure 3. Results of Experiment 2. Magazine approach is shown to the stimulus paired with a second outcome at a temporal distance (S1) or immediately before (S2) the test. Responding is shown at the end of training with the second outcome and over the course of the test during each stimulus and during a prestimulus period.

	Condit	Second O	Rest	Second O	Test
Group D	S1-01	S1-02		S2-01	S1
	S2-02				S2
Group S	S1-01	S1-01		S2-02	S1
	S2-02				S2

Figure 4. Design of Experiment 3. Two groups of animals were given training with each of two stimuli. Each stimulus then received training with a second outcome, one before and one after a delay that intervened prior to the test. For Group D, the second outcome was different from that used in initial training; for Group S, it was the same.

Procedure

Pavlovian conditioning. The animals received initial magazine training with pellets and sucrose, as in Experiment 1. They then received Pavlovian conditioning on each of 14 days. Each session contained eight 30-sec presentations each of L and N. For half of the animals, L terminated in pellets and N terminated in sucrose; for the other half of the animals, the outcomes were interchanged.

Second Outcome Phase 1. On each of the next 2 days, the animals received 16 presentations of either L or N, counterbalanced across the conditioning treatment. For Group D, the stimulus was followed by the outcome different from that used in conditioning; for Group S, it was followed by the same outcome. This phase lasted 2 days.

Rest. On each of the next 6 days, the animals remained in their home cages and were maintained on their deprivation schedule.

Second Outcome Phase 2. Second Outcome Phase 2 was identical to Phase 1 except that the alternative stimulus was given and was paired with the outcome not used in Phase 1. This phase also lasted 2 days.

Test. The test was administered in a manner identical to that of Experiment 1. Four nonreinforced presentations each of L and N were added onto the end of the 2nd day of Phase 2.

Results and Discussion

Pavlovian conditioning of magazine entry proceeded smoothly. By the final day of initial training with pellets and sucrose, the mean entries per minute were 6.8 and 20.0 during the pre-CS and CS periods, respectively. There were no systematic differences as a function of Group, CS, or outcome identity. Over the course of the second phase, performance remained at approximately the same level.

Figure 5 shows the performance on the final half-session of training with the second outcome and over the course of testing. Responding is shown separately for Groups S and D, for the pre-CS period and for the stimuli that received their second outcome training immediately after conditioning (8 days earlier) or immediately before testing.

Group D (open symbols) showed a data pattern like that observed in Experiment 2. The stimulus trained immediately after conditioning and then given the opportunity to recover showed greater responding over the test as a whole than did the stimulus trained shortly before the test [$T(8) = 4, p < .05$]. On the other hand, Group S showed a quite different pattern, with similar levels of responding on both of its stimuli whether or not there

was an opportunity for recovery [$T(8) = 18$, n.s.]. Moreover, there was greater responding in Group D, compared with Group S, for the stimulus given the opportunity for recovery [Mann-Whitney $U(8,8) = 13, p < .05$]. These results replicate those of Experiment 2 and suggest that the recovery effect depends on the use of a different outcome from that employed in original training.

This finding of dependence on the use of different outcomes helps us evaluate the possible contributions of two other temporally based processes to the growth in responding with time since second training. First, recent exposure to an outcome might produce a local satiation for that outcome (e.g., Mook, Brane, Kushner, & Whitt, 1983), which could temporarily depress responding to stimuli associated with it. With time since that exposure, one would expect recovery from satiation and consequent increases in performance. But such a satiation effect would be expected to have as large a differential effect on responding to S1 and S2 in Group S as in Group D. Second, there is some evidence for the broadening of stimulus generalization gradients with the passage of time (see Riccio, Ackil, & Burch-Vernon, 1992). Although the exact impact of such a change is unclear, it seems possible that such a broadening permits higher levels of test responding to a stimulus whose most recent training was farther in the past because of less susceptibility to any changes that result from the testing procedure itself. However, such a process should have a similar impact in Group D and Group S.

EXPERIMENT 4

Experiment 4 repeated Experiment 3 but with changes in design that provided a within-subject systematic replication and that used a more conventional procedure for studying recovery. The experimental design is schematized in Figure 6.

Initially, two stimuli, S1 and S2, signaled different outcomes, O1 and O2. Then, for several sessions, both stimuli signaled one outcome, O1. Finally, after a rest period, both stimuli were tested. The question is whether there will be more responding to S2, the stimulus trained with two outcomes, compared with S1, the stimulus trained with one outcome, following the rest period. With this de-

Figure 5. Results of Experiment 3. Magazine approach is shown to the stimulus paired with a second outcome at a temporal distance (S1) or immediately before (S2) the test. Responding is shown at the end of training with the second outcome and over the course of the test during each stimulus and during a prestimulus period. The top panel shows the results of a group for whom the two outcomes paired with each stimulus differed from each other. The bottom panel shows the results of a group for whom they were the same.

sign, a more sensitive within-subject comparison is made between S1 and S2. Responding to S1 and S2 at the end of Phase 2 training provides a baseline for comparison with that after the rest period. It was anticipated that differences in responding would develop with time.

This design has some of the same shortcomings as described earlier for a standard spontaneous recovery design. The test assesses performance to the stimuli later in the animal's life and after exposure to additional treatment, compared with the performance demonstrated at

the end of Phase 2 treatment. For that reason, comparison of responding to a particular stimulus at the end of Phase 2 with that in the test is not very informative. Of more interest is the comparison between performance to S1 and S2 after the rest. That comparison more closely matches extraneous factors other than the differential treatment with different outcomes.

This design also addresses a potential problem with the designs used in the other experiments reported here. In those experiments, comparison was made between stim-

Training	Second-O	Rest	Test
S1-O1	S1-O1		S1
S2-O2	S2-O1		S2

Figure 6. Design of Experiment 4. Two stimuli initially received training with different outcomes (O1 and O2). Both stimuli were then immediately given training with O1. Finally, both were tested after a delay.

uli treated at different times after initial training. This resulted in the required different rest times before the test, but it also resulted in confounded differences in both the times between original training and treatment and the order in which the stimuli were treated. For instance, in Experiment 1, S1 was extinguished immediately after training, whereas S2 was extinguished after a delay; perhaps more importantly, S1 was always the first stimulus extinguished and S2 was always the second stimulus. In Experiment 4, the two stimuli both received their Phase 2 treatment at the same time and in intermixed order. They differed only in whether the outcome used in Phase 2 was the same or different from that used in Phase 1.

Method

Subjects and Apparatus

The subjects were 16 naive male rats of the same sort and maintained in the same manner as in Experiment 1. The apparatus was that of Experiment 2.

Procedure

Pavlovian conditioning. The animals received initial magazine training with pellets and sucrose, as in Experiment 1. They then received Pavlovian conditioning on each of 14 days. Each session contained eight 30-sec presentations each of L and N. For half of the animals, L terminated in pellets and N terminated in sucrose; for the other half of the animals, the outcomes were interchanged.

Second Outcome Phase. On each of the next 4 days, all animals received eight presentations each of N and L. For half of the animals, both stimuli terminated in a pellet; for the other half, it terminated in sucrose. The result was that, for half of the animals, N received a different outcome from that of training and L received the same outcome, whereas, for the other half of the animals, those treatments of L and N were interchanged.

Rest. On each of the next 6 days, the animals remained in their home cages and were maintained on the deprivation schedule.

Test. On the next day, the animals received a single test session. Four presentations each of L and N were given without reinforcement. The data of primary interest are the response rates to L and N during this test.

Results and Discussion

Pavlovian conditioning of magazine entry proceeded smoothly. By the final day of initial training with pellets and sucrose, the mean entries per minute were 4.6 and 20.4 during the pre-CS and CS periods, respectively. There were no systematic differences as a function of CS or outcome identity. Over the course of training with the second outcome, responding remained reasonably stable. The mean responses per minute were 4.4 and 18.2 in the pre-CS and CS periods, respectively.

Figure 7 shows the mean response rates during the final half-session of training with the second outcome and over the course of the test session, separated according to whether the stimulus received the same or different outcome from that used in original training. Overall, the level of performance was lower during the test than at the end of the Phase 2 training. However, during the test session, both stimuli elevated responding relative to the pre-CS period. More importantly, the amount of that elevation was greater for the stimulus that had been trained with the different outcome. That difference proved reliable for the first block of test trials [$T(15) = 25, p < .05$]. Examination of the response rates during the final session of training with the second outcome failed to reveal a similar difference. The superiority in responding to the stimulus trained with a different outcome, compared with that trained with the same outcome, was greater during the test than it was at the end of second outcome training [$T(16) = 23, p < .05$].

These results confirm those of Experiment 3, using a somewhat different design. With the passage of time, a stimulus trained successively with two outcomes came to control a higher level of responding than did one trained with only one outcome. A similar difference was absent prior to the passage of time, suggesting the recovery of some process.

GENERAL DISCUSSION

These experiments suggest that with time there is spontaneous recovery after a Pavlovian S-O1 association has been subjected either to omission of O1 or to a replacement of O1 by O2. That recovery was detected using a within-subject procedure that assesses stimuli at the same point in time and at the same distance from original training but at different temporal distances from the point of omission or replacement of O1. It also appeared with a more conventional spontaneous recovery procedure.

These observations suggest that the pairing of a stimulus with a second outcome shares certain features with extinguishing that stimulus. One way to think of this sharing is to note that when S-O1 training is followed by S-O2 training, then S is repeatedly presented without the O1. Although one would normally expect that to result in deterioration of the response to S, the new pairing with O2 apparently prevents deterioration. Nevertheless, the fact that there is an increase in responding to S with time suggests that, at least, the portion of nonreinforcement that generates recovery is also present with O2 training, despite the lack of deterioration. An analogous observation has been made for the case of instrumental training in which R is first paired with O1 and then with O2 (Rescorla, 1996b). Borrowing from a suggestion made for that case, we may think of successive training with O1 and then O2 as establishing both S-O1 and S-O2 associations, with a result that the total associative strength is inappropriately high during O2 training. That "overexpectation" might result in the development of some inhibitory process, in the same way that one can envision

Figure 7. Results of Experiment 4. Responding is shown to two stimuli at the end of training with a second outcome and during a test after a delay. One stimulus (S2) had received training with two different outcomes; the other (S1) had received equivalent training but with a single outcome.

that extinction could result in the overexpectation of O1 following simple S–O1 training.

The nature of this inhibitory process remains to be better explored. One possibility is that there is an inhibitory association set up between S and O1 during extinction or reinforcement with O2. However, other results suggest that after successive training with O1 and then O2, the associations involving O1 are just as strong as those involving O2 (e.g., Delamater, 1996; Rescorla, 1992).

Another possibility is that there is a change in which association is retrieved, with S–O1 dominating at the end of original training but S–O2 dominating after O1 is replaced with O2. In this view, both associations remain intact but differ in their likelihood of retrieval (e.g., Bouton, 1991). With the passage of time, the balance might shift away from the retrieval of S–O2 back toward the retrieval of S–O1. This view provides a natural account for spontaneous recovery after extinction, when O2 is simple nonreinforcement and would support little behavior. In that case, the increasing likelihood of retrieving S–O1 would mean an increasing likelihood of performance. However, this view provides a less natural account of the case examined in Experiments 2, 3, and 4, when O1 and O2 are similarly valued outcomes. In that case, there is no reason to anticipate that retrieving the S–O1, rather than the S–O2, association would result in augmented responding. What would be needed is a more explicit retrieval hypothesis that allows activation of multiple associations to combine in some fashion to augment responding.

A third mechanism that has been suggested for the decrement observed during extinction and spontaneous recovery is the reduction in processing of the CS. For instance, Robbins (1990) argued that extinction might result in loss of attention to the CS, but that attention might recover with the passage of time. One observation that

encouraged this account was that a CS trained both as an excitator and separately as a modulator lost both functions when it underwent extinction. Moreover, both recovered together with the passage of time. However, this view seems less attractive for the case in which a stimulus is paired first with one outcome and then with another. Presumably, training with the second outcome would maintain attention to the stimulus, as is evidenced by continued responding. To the degree that spontaneous recovery from this training involves the same mechanism as spontaneous recovery from extinction, it seems more likely that loss of attention is a result, rather than a cause, of extinction and spontaneous recovery.

A fourth possibility is that nonreinforcement and replacing O1 with O2 result in a decremental process that involves the response. For instance, such training might superimpose on the S–O1 and S–O2 associations an inhibitory association between S and the response, S–|R. An inhibitory association between the stimuli and the making of a magazine response, could prevent performance while allowing preservation of the previously learned stimulus–outcome associations. If that inhibitory association with the magazine response were to fade with time, it would allow for some increase in performance. It would also be consistent with other observations suggesting the excellent preservation of the S–O1 and S–O2 associations after such manipulations.

Although the present procedures of training a stimulus successively with two outcomes can be viewed as an instance of “counterconditioning,” they are unusual in that both outcomes generate the same conditioned response. This is of particular interest because it makes contact with earlier Pavlovian and instrumental experiments that use other techniques to evaluate the status of the separate associations with O1 and O2 under such training conditions.

Moreover, the observation of a result such as spontaneous recovery despite maintenance of the same response through training with a second outcome is especially striking evidence for the involvement of an extinction-like process in counterconditioning. It is much less surprising to find recovery with time in a response whose likelihood actually declined during the counterconditioning. Nevertheless, it is unclear whether outcomes that generate the same response involve the same processes as do outcomes that generate different, and perhaps competing, responses.

In any case, the present results suggest that substitution of one outcome by a different one can allow substantial preservation of the original Pavlovian associations. Moreover, that substitution contains some of the features of an extinction procedure, such as those that result in spontaneous recovery.

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