

Outcome-selective effects of intertrial reinforcement in a Pavlovian appetitive conditioning paradigm with rats

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The outcome-selective effects of presenting intertrial unconditioned stimuli (USs) in a rat appetitive conditioning paradigm were examined in two experiments. In both experiments, two stimuli were paired with different outcomes, while one of these outcomes was also presented in the intertrial interval (A+, B*, +). Two measures of learning, stimulus-elicited magazine approach and Pavlovian-to-instrumental transfer, were used to examine these effects. The presence of freely occurring outcomes in the intertrial interval (ITI) was observed to interfere more with the learning of a new association (Experiment 1) and to degrade more an already established association (Experiment 2) when the conditioned stimulus had been paired with the same outcome as that occurring in the ITI. An outcome-selective effect of ITI USs distinguishes among accounts of contingency based on general performance, attentional, and motivational mechanisms from those based on more specific associative mechanisms. Overall, the data highlight the importance of specific encoding processes in the analysis of associative learning.

A convenient framework in which to conceptualize conditioning is that provided by the contingency between two events (Rescorla, 1967). This framework has led to the expectation that presentation of reinforcement in the absence of some target event (a conditional stimulus or instrumental response) should have deleterious effects on conditioned responding. This result has been observed in a wide variety of situations with both Pavlovian and instrumental paradigms (Bouton, Rosengard, Achenbach, Peck, & Brooks, 1993; Durlach & Shane, 1993; Farwell & Ayres, 1979; Hearst & Franklin, 1977; Hammond, 1980; Rescorla, 1968), although not without important qualifications (see Durlach, 1989; Jenkins, 1984; Papini & Bitterman, 1990).

One particularly important issue that has been addressed in the instrumental paradigm, but not so thoroughly in Pavlovian paradigms, is the extent to which intertrial (or interresponse) reinforcers have outcome-selective deleterious effects on performance. Several investigators have reported outcome-selective effects (Colwill & Rescorla, 1986; Dickinson & Mulatero, 1989; Williams, 1989). In the Colwill and Rescorla study, for instance, rats were first trained on a concurrent schedule

to leverpress for one outcome (e.g., pellets) and to chain-pull for another (e.g., sucrose). After both responses were well trained, the contingency between one of the response-outcome pairs was degraded by the presentation of additional noncontingent deliveries of that outcome at times when neither response occurred. This procedure resulted in greater suppression of the response that otherwise produced the outcome in question.

This result is valuable for analyses of contingency using any procedure, Pavlovian and instrumental alike: It suggests that the nature of the impairment one observes with the introduction of noncontingent reinforcement is related to reinforcer-specific, as opposed to more general, processes. For instance, it is known from postconditioning reinforcer-revaluation experiments (Colwill & Rescorla, 1986; Delamater & LoLordo, 1991) that an animal's representation of learning is detailed enough to code sensory-specific features of the reinforcer. Observations of outcome-specific effects of noncontingent reinforcement suggest that it is these sensory-specific processes that contribute to the impairment.

While there have been several demonstrations of outcome-specific effects of noncontingent reinforcement using instrumental paradigms, only one study has examined the issue in a Pavlovian paradigm. Stanhope (1990) examined this issue using a pigeon autoshaping procedure with an experimental design that was conceptually similar to that used by Colwill and Rescorla (1986). The results from Stanhope's experiment, however, were difficult to interpret given reported differences in the value of the two outcomes that were used. While the low-valued outcome (water) exerted selective effects upon conditioned responding when it was pre-

This research was supported by a grant from the National Science Foundation (BNS-88-03514) to Robert A. Rescorla and a National Research Service Award Postdoctoral Fellowship (MH-10007) to the author. I gratefully acknowledge Bob Rescorla for his helpful comments on previous versions of this manuscript. Reprint requests may be directed to the author at the Psychology Department, Brooklyn College—CUNY, 2900 Bedford Ave., Brooklyn, NY 11210-2889.

—Accepted by previous editor, Vincent M. LoLordo

sented noncontingently during the intertrial interval (ITI), the high-valued outcome (grain) exerted nonselective effects when it was the intertrial reinforcer.

The present experiments explored the potential for outcome-selective effects of intertrial reinforcement on Pavlovian learning in a situation more similar to those in which selective effects have been reported for instrumental learning. The present studies used a Pavlovian appetitive conditioning procedure with rats (Farwell & Ayres, 1979; Holland, 1979). Importantly, the two reinforcers used here (pellets and sucrose) were the same as those used by Colwill and Rescorla (1986) to demonstrate outcome-selective effects in their instrumental conditioning experiment.

In the present studies, outcome-selective effects of USs occurring in the ITI were examined not only in acquisition (Experiment 1), as in the Stanhope (1990) study, but also after learning had already taken place (Experiment 2), as in the instrumental studies. Two measures of conditioning were used in the present experiments. The measure of conditioning typically used to study appetitive conditioning in rats is the magazine approach response (e.g., Bouton et al., 1993; Durlach & Shane, 1993). This measure also was used in the present study. However, because inferences about which specific features of learning become part of the underlying associative structure cannot be made using a measure such as this (see Holland, 1979; Rozeboom, 1958), an additional measure of learning was used. The transfer-of-control test is especially valuable at detecting specific stimulus-outcome associations (Colwill & Rescorla, 1988; Kruse, Overmier, Konz, & Rokke, 1983; Rescorla, 1991). In this test, the presence of specific stimulus-outcome associations is inferred from the degree to which the stimulus selectively transfers its control to separately trained instrumental responses on the basis of shared outcomes. This type of selective transfer can occur only if specific stimulus- and response-outcome relations are encoded. By using the transfer of control test in the present studies, it was hoped that the effects of the contingency procedure on the specific stimulus-outcome associations could be assessed more directly than would be possible by monitoring magazine approach.

EXPERIMENT 1

The first experiment examined outcome-specific effects of ITI unconditioned stimuli (USs) on stimuli that are undergoing acquisition. During the Pavlovian training phase, one stimulus (A) was reinforced with one outcome (+) and another stimulus (B) was reinforced with a second outcome (*). In addition, A's outcome also occurred in the ITI. Following this training, A and B were transferred in a choice test to two instrumental responses that earlier had been reinforced with the different outcomes used in Pavlovian training.

Method

Subjects

Sixteen male Sprague-Dawley rats, weighing between 475 and 600 g at the beginning of the experiment, were individually housed in a colony room maintained on a 16-h-light/8-h-dark cycle. The rats were reduced to and maintained at 80% of their free-feeding body weights with daily supplemental feedings.

Apparatus

The apparatus consisted of four identical operant chambers, each of which was housed in a sound- and light-resistant shell. The operant chambers measured 22.9 × 20.3 × 20.3 cm. Two end walls were constructed of aluminum, and the side walls as well as the ceiling were made from clear Plexiglas. The floor consisted of 0.48-cm stainless steel rods spaced 1.9 cm apart center to center. Centered on one end wall 10 mm above the grid floor was a recessed magazine measuring 30 × 36 × 20 mm. A single 45-mg pellet (Formula A, P. J. Noyes Co., Lancaster, NH) was dropped onto the magazine floor when this reinforcer was scheduled, and 0.3 ml of an 8% (wt./vol.) sucrose solution was delivered through a gravity-feed valve into a small well, the top of which was level with the magazine floor, when this reinforcer was scheduled. On the inner walls of the recessed magazine were an infrared detector and emitter enabling the automatic recording of head movements inside the magazine. To the left of the magazine was located a lever, and to the right, through a hole in the ceiling, was suspended a chain that was connected to a microswitch. When not used, the lever was covered with a metal shield and the chain was withdrawn from the chamber. Located above the chamber and attached to the back wall of the outer shell was a speaker through which a white-noise stimulus was presented. This noise stimulus measured 5 dB above a background level of 84 dB (C weighting). Next to the speaker was located a 6-W light bulb, covered with a small lamp shade to diffuse the light. The chamber was always dark except when the visual conditioned stimulus was presented. Fans attached to the outer shells provided cross-ventilation within the shell and background noise. All experimental events were controlled and recorded automatically by a microcomputer and interfacing equipment located in an adjacent room.

Procedure

Initially, rats were given one magazine training session with each reinforcer. Each of these sessions was 20 min in duration, and the reinforcer was presented on an average of once a minute for a total of 20 presentations.

Instrumental conditioning. Following magazine training, each rat was instrumentally conditioned with the lever and chain. Using a continuous reinforcement schedule, the rats were taught initially to leverpress for one outcome (pellets or sucrose) until approximately 70 reinforcements had been earned. Rats were then taught to chainpull for the other outcome (sucrose or pellets) in a separate session. The particular response-outcome contingencies were counterbalanced across subjects. Six days of instrumental training on a random interval (RI) 60-sec schedule of reinforcement then followed. Two 20-min sessions, separated by approximately 60 min, occurred on each of these days. The lever was the only response manipulandum present during one session; the chain was the only manipulandum present during the other. The order of training with the lever and chain was balanced across days.

Pavlovian conditioning. After instrumental conditioning, all rats were exposed to the chambers without any manipulanda or reinforcements present in two 20-min sessions. These sessions were designed to attenuate any context conditioning that might have developed as a result of instrumental training prior to exposure to the Pavlovian contingencies.

A Pavlovian contingency procedure was used over the next 16 consecutive daily sessions. Each 26-min session contained four 10-sec presentations each of stimulus A, stimulus B, and four equally long no-stimulus "dummy" intervals during which intertrial responding was measured. Noise and light were counterbalanced across subjects in their roles as stimulus A or stimulus B. Three of the four A and B trials ended in reinforcement. For half of the subjects, sucrose served as the US on A trials and pellets served as the US on B trials; the other rats received the reverse stimulus-reinforcer relations. The average ITI, measured from stimulus offset to the next onset, was just over 3 min.

In addition, 24 reinforcements of one type were randomly presented during the ITIs, with the constraint that only one A, one B, and one dummy trial had an ITI US occurring within 15 sec prior to their onsets. This constraint ensured that data that were uncontaminated by reinforcer-elicited magazine responding could be collected from the remaining three A, B, and dummy trials in each daily session. This condition would on average have been met without this constraint. The intertrial reinforcer was always the same as that used to reinforce stimulus A. Note that this manipulation only weakly degraded the contingency for stimulus A, given that the rate of reinforcement in A remained greater than the rate in the ITI (i.e., 4.5 per min in A vs. 1 per min in the ITI). Stimulus B, when it was reinforced, was paired with the outcome that did not occur in A and the ITI. Whether the ITI reinforcer was pellets or sucrose was counterbalanced across subjects and stimulus condition. Four event sequences that differed in terms of the order of A and B trials, the ITIs, and the placement of ITI USSs were repeated irregularly in four-session blocks.

Instrumental transfer tests. Following the Pavlovian conditioning, the A and B stimuli were tested for their ability to influence instrumental responding in a choice test. In preparation for this test, the rats received one 20-min session of instrumental training with each manipulandum separately. These sessions occurred on 1 day and were separated by about 60 min. On the next day, all rats received one 8-min extinction session in which both manipulanda were present. This brief extinction session was intended to familiarize the rats with the choice procedure.

The first Pavlovian-to-instrumental transfer test session occurred on the following day. This session was 16 min in duration and contained four A and four B stimulus presentations superimposed on the choice baseline. The duration of the stimuli was increased from 10 sec in training to 30 sec in the test in order to obtain a more stable estimate of responding. The noise (N) and light (L) stimuli were presented in the following order: NLNLLNLN. The session began 30 sec after a rat was placed in the chamber. Each 30-sec stimulus presentation was preceded by a 30-sec pre-stimulus interval and followed by a 1-min poststimulus interval. On the next day, the rats received one more instrumental retraining session. A second transfer test that was identical to the first was conducted on the day after instrumental retraining. Magazine entries during presentations of the stimuli were also recorded during test sessions.

Statistical Analysis

One-way analysis of variance (ANOVA) techniques and the post hoc testing method of Rodger (1974, 1975) were used to statistically evaluate the data. Rodger's method entails the selection of a mutually orthogonal set of post hoc contrasts, which are evaluated against his (1975) tabled values of $F[E\alpha]$. Type I error rate was held constant on a per decision basis at $\alpha = .05$. Furthermore, with a sample size of 16, the power of detecting small to moderately sized effects with this technique reaches 0.95. This feature of the analysis allows the same statistical weight to be given to null hypotheses that are accepted or rejected.

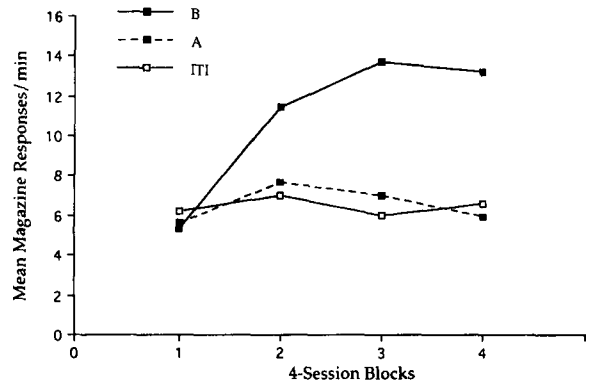


Figure 1. Mean magazine response rates (responses/minute) in the presence of stimulus A, stimulus B, and an equivalent ITI period throughout the acquisition phase of Experiment 1. Stimuli A and B were paired with different outcomes, and A's outcome also was presented in the ITI (A+, B*, +).

Results and Discussion

The magazine response data from the Pavlovian contingency phase are shown in Figure 1. That figure displays the mean magazine response rates averaged over four-session blocks for the stimuli, A and B, and the ITI dummy interval. Over the course of acquisition, responding emerged only to stimulus B—that is, the stimulus whose reinforcer did not also occur in the ITI.

Data from the final two blocks of training were statistically analyzed using a one-way repeated measures ANOVA, which yielded a significant main effect of stimulus condition [$F(2,30) = 4.01$]. Post hoc analyses revealed that responding did not differ between stimulus A and the ITI period, but that the responding in both combined was less than that in stimulus B [$F(2,30) = 3.99$]. These tests statistically imply that the population means underlying the observed scores are ordered as follows: $B > A = ITI$. This analysis was supported by a further contrast showing that responding in stimulus B during the final two blocks of trials increased, relative to that in the first training block, more than it did in stimulus A [$F(1,15) = 4.55$].

This difference in magazine responding to stimuli B and A was influenced by the particular outcome that occurred in the ITI. The difference between B and A was larger when pellets were presented in the ITI ($B_{\text{sucrose}} = 21.6$ and $A_{\text{pellets}} = 8.5$ responses/min) than when sucrose was the ITI reinforcer ($B_{\text{pellets}} = 5.3$ and $A_{\text{sucrose}} = 4.3$ responses/min). It is typically the case in this laboratory that, in the absence of any intertrial USSs, stimuli predictive of sucrose evoke more magazine responses than do stimuli predictive of pellets. Perhaps the differential effect of ITI pellets and sucrose in the present study occurred because the selective effect of intertrial sucrose on magazine responding was diminished by the tendency of an A–sucrose association to be expressed more

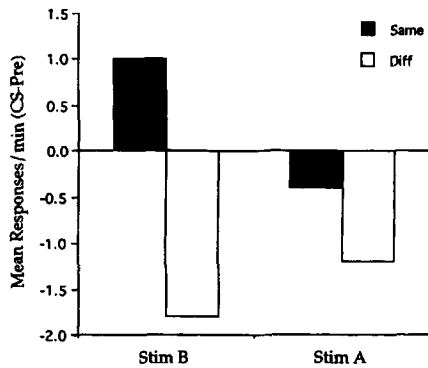


Figure 2. Mean instrumental responses/minute (CS-Pre) during stimulus B and stimulus A in the transfer tests of Experiment 1. Data are shown separately for the instrumental responses that were reinforced with the same or different outcome as that paired with B and A.

strongly in magazine responses than a B–pellet association. The transfer-test data are consistent with this suggestion.

Data from both transfer tests were combined and are presented in Figure 2. Response rates, averaging 3.7 responses/min, did not differ in the prestimulus periods among the conditions. Mean difference scores (responses in the 30-sec stimulus period minus responses in the 30-sec prestimulus period) are organized in the figure according to whether the reinforcer for the instrumental response was the same as or different from the outcome signaled by stimulus A or stimulus B. Only stimulus B selectively influenced choice: responding increased on the manipulandum that was reinforced by the same outcome as was signaled by stimulus B and concurrently decreased on the other manipulandum. Although a same versus different effect appears to have occurred for stimulus A as well, this difference is largely due to one aberrant subject. Median difference scores for stimulus A ($A_{\text{same}} = -0.3$; $A_{\text{different}} = -0.4$) eliminate the influence of this subject and indicate that A had little effect on choice. Medians for stimulus B ($B_{\text{same}} = 1.0$; $B_{\text{different}} = -1.5$), however, parallel the difference in mean responding.

Difference scores were statistically evaluated with a repeated measures ANOVA, which yielded a significant main effect of stimulus condition [$F(3,45) = 3.56$]. Post hoc tests yielded a significant difference between the same and different responses to stimulus B [$F(3,45) = 3.13$] but not to stimulus A [$F(3,45) = .03$]. A final contrast indicated that overall responding (same + different) to B and to A was equal. These statistical decisions imply the true population means to be ordered as follows: $B_{\text{same}} > A_{\text{same}} = A_{\text{different}} > B_{\text{different}}$. Thus, stimulus B (but not stimulus A) selectively transferred its control to instrumental responding.

The selective transfer of stimulus B to instrumental responses was partly a result of the suppression of the different-outcome response, rather than being solely due to facilitation of the same-outcome response. This result

is not uncommon when Pavlovian stimuli are tested in the manner used here (cf. Colwill & Rescorla, 1988). The suppression of the different-outcome response might reflect competition from the tendency of stimuli to evoke magazine responses. Alternatively, this outcome could reflect a redistribution of responding during the choice test in favor of the same-outcome response. Nonetheless, regardless of the specific mechanism involved, it would appear that the inclusion of ITI USs selectively precludes A from either acquiring or expressing outcome-specific information.

The differential ability of B, but not of A, to transfer to instrumental responding was independent of the identity of the ITI event (pellets or sucrose). The size of the same-different effect in response to B during transfer testing was very similar in the two subgroups [$F(1,14) = 0.01$]. The failure to observe a differential effect of stimulus A also was similar in the two subgroups [$F(1,14) = 1.06$].

The data from this experiment suggest that ITI USs interfere with conditioning to stimuli undergoing Pavlovian acquisition in an outcome-selective manner. This effect depended somewhat upon the nature of the inter-trial US (also see Stanhope, 1990), as indicated by the magazine response measure. However, the nature of the ITI US did not influence transfer testing. The latter result supports the idea that the asymmetrical effect of ITI USs on magazine responding was a performance effect rather than an associative one.

Surprisingly, the deleterious effects of ITI USs on the CS paired with that US were complete. There was no evidence that stimulus A acquired an association with its US, even though the rate of its US was greater in its presence (4.5/min) than in the ITI (1/min). These parameters support acquisition in other paradigms, most notably pigeon autoshaping (Gibbon & Balsam, 1981). In light of this discrepancy, it would be valuable to know the extent to which the invariant relationship between acquisition and the ratio of cycle-to-trial reinforcement rates that holds in the pigeon autoshaping paradigm applies to the rat appetitive conditioning paradigm.

EXPERIMENT 2

In Experiment 1, outcome-selective effects of ITI USs were studied in acquisition. In Experiment 2, these effects were examined after learning had already developed. Postacquisition effects of ITI USs have been studied most extensively using the pigeon autoshaping paradigm. In this procedure, ITI USs have different effects on conditioned responding, depending on whether they are presented during acquisition or in the steady state. While the presence of ITI USs prevents the development of autoshaped keypecks, the decremental effect of this treatment on already-established keypecks is substantially reversible (Durlach, 1986; Lindblom & Jenkins, 1981; Rescorla, 1989). This result suggests that ITI USs do not impair associations that are acquired prior to degradation of the stimulus-outcome contingency.

The deleterious effect of ITI USSs upon conditioned magazine responding in a rat appetitive conditioning paradigm, however, appears to be more stable (Durlach & Shane, 1993). It is worth investigating further the durability of this decremental effect using measures that can specifically gauge the status of particular CS-US associations.

The present experiment, therefore, examined whether ITI USSs would exert outcome-selective deleterious effects on previously established associations using both the conditioned magazine response and the transfer measures. It seemed possible that the effects of ITI USSs in this situation might depend upon how they were measured. The transfer measure might be taken as a "purer" index of specific stimulus-outcome associations than the magazine approach. If so, the more durable deleterious effects of ITI USSs on magazine responses could reflect an effect on processes other than associative ones. Using a relatively direct associative measure such as transfer, one might obtain the substantial recovery also observed in the pigeon autoshaping paradigm. This pattern of data would support the observation that although a procedure that degrades the contingency following acquisition has deleterious effects on performance, it does not harm the association.

Method

Subjects and Apparatus

Sixteen male Sprague-Dawley rats, weighing between 400 and 600 g at the beginning of the experiment, were individually housed and maintained like those in the first experiment. The apparatus was the same as in Experiment 1.

Procedure

Following magazine training, instrumental conditioning, and context extinction, the rats received 16 sessions of Pavlovian conditioning, as in Experiment 1. The only exception was that no intertrial reinforcers were presented during the Pavlovian conditioning phase. After initial Pavlovian training to both stimuli, the rats received an additional 28 sessions in which reinforcers were presented in the ITI at a rate of 1/min, as in Experiment 1. Pellet and sucrose presentations occurring in the ITI were counterbalanced across animals. Following this training, the effect of these stimuli on chainpull and lever responding was assessed in a Pavlovian-to-instrumental transfer test using the same procedures as in Experiment 1. After this test, the rats were exposed in eight additional sessions to the Pavlovian contingency procedure in which the rate of ITI reinforcers was doubled (2/min) relative to the first training sessions. Following two instrumental retraining sessions, the stimuli were again tested for their effect on instrumental choice responding in two consecutive daily transfer sessions.

Results and Discussion

The magazine response data from the Pavlovian conditioning and subsequent contingency phases are shown in Figure 3. Mean magazine response rates occurring to stimulus A, stimulus B, and the dummy ITI period are presented in two-session blocks in each phase. Responding gradually emerged to stimuli A and B over the course of the initial acquisition phase to an asymptotic level of about 15 responses/min. Responding in the ITI

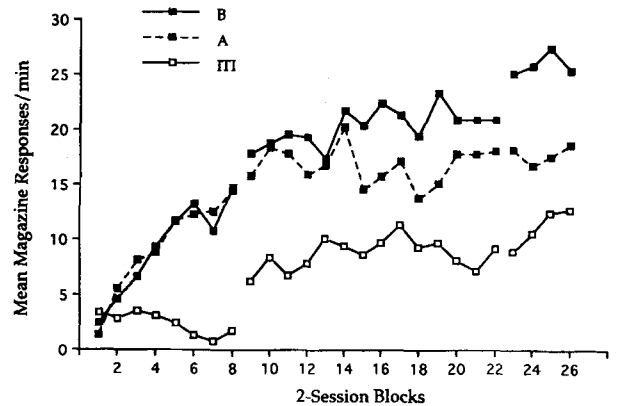


Figure 3. Mean magazine response rates in the presence of stimulus A, stimulus B, and an equivalent ITI period throughout the acquisition phases of Experiment 2. Stimuli A and B were paired with different outcomes in the first phase, and A's outcome was also presented in the ITI during the second (1/min) and third (2/min) phases (A+, B*/A+, B*, +). Transfer tests occurred between the second and third phases and after the third phase.

was near zero by the end of this phase. When A's outcome was introduced in the ITI at a rate of 1/min, the overall rate of responding in the presence of both stimuli continued to increase, and the rate in the ITI increased abruptly. However, differential responding to A and B developed slowly. Doubling the rate at which A's outcome occurred in the ITI in the final training phase enhanced differential responding to A and B.

A repeated measures ANOVA performed on mean response rates for the final eight sessions yielded a significant main effect of stimulus [$F(2,30) = 8.43$]. Post hoc tests revealed that B differed from the ITI [$F(2,30) = 8.38$] and that A did not differ from average responding in the B and ITI conditions combined [$F(2,30) = 0.03$]. These statistical decisions imply the following order among the population means: $B > A > ITI$. The statistical inference that B differed from A also was supported by a direct comparison between B and A after subtracting their asymptotic scores from the final four pre-ITI US sessions [$B = 13.3$ responses/min and $A = 4.4$ responses/min; $F(1,15) = 6.34$].

This conclusion was further supported by the magazine data collected during the transfer tests. Because the difference between stimulus A and stimulus B was similar in each test session (averaging 15.5, 13.2, and 11.3 responses/min for B in the three tests, respectively, and 10.7, 10.1, and 8.0 responses/min for A in the three tests, respectively), data were averaged across all three tests. More magazine responses were evoked by stimulus B (mean = 13.3 responses/min) than by stimulus A (mean = 9.6 responses/min) [$F(1,15) = 7.68$]. This result is important in showing that stimulus A had not fully recovered from its reduced response rate, in spite of the fact that the transfer tests were performed in extinction (also see Durlach & Shane, 1993). If there was any recovery

over these three extinction sessions, it was not as impressive as that reported by Durlach (1986), Lindblom and Jenkins (1981), and Rescorla (1989), using the pigeon autoshaping paradigm.

As in the previous experiment, the difference in magazine responding between the stimuli was influenced by the nature of the ITI reinforcer. A larger difference occurred over the final eight training sessions in the subgroup receiving pellets in the ITI ($B_{\text{sucrose}} = 29.8$ responses/min vs. $A_{\text{pellets}} = 13.1$ responses/min) compared with sucrose ($B_{\text{pellets}} = 22.0$ responses/min vs. $A_{\text{sucrose}} = 22.6$ responses/min). These comparisons, however, are complicated by the overall difference between sucrose and pellets in supporting CS-evoked magazine responding. The additive effect of the contingency and underlying sucrose/pellet differences in conditioning magazine responses to the CSs is best seen by comparing response rates when both stimuli (in different subgroups) were reinforced with sucrose ($B - A = 7.2$ responses/min) or with pellets ($B - A = 8.9$ responses/min).

Data from the transfer tests are presented in Figure 4. The figure displays mean instrumental responding combined over the three tests for each stimulus according to whether the outcome reinforcing the response was the same as or different from that paired with the stimulus. The prestimulus response rates did not differ across the various conditions, averaging 3.6 responses/min. The figure shows that a same versus different effect occurred in response to stimulus B, but not to stimulus A.

A repeated measures ANOVA on these data yielded a significant main effect of stimulus condition [$F(3,45) = 2.13$]. Post hoc tests revealed that the same-outcome response for stimulus B was responded to at a higher rate than were all of the other conditions [$F(3,45) = 2.12$]; the latter conditions did not differ from each other [$F_s < .005$]. This set of statistical decisions implies that the underlying population means are ordered as follows: $B_{\text{same}} > B_{\text{different}} = A_{\text{same}} = A_{\text{different}}$. Thus, only stimulus B acted selectively in these tests.

Further inspection of the data revealed that the effect just described might have been underestimated when the

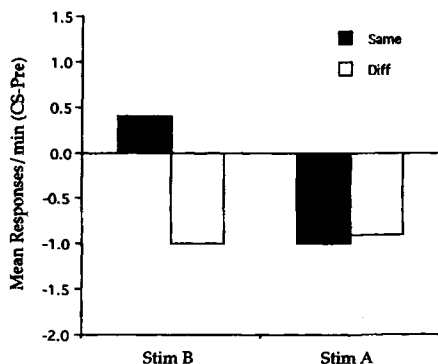


Figure 4. Mean instrumental response rates (CS-Pre) during stimulus B and stimulus A in the transfer tests of Experiment 2. Data are shown separately for the instrumental responses that were reinforced with the same or different outcome as that paired with B and A.

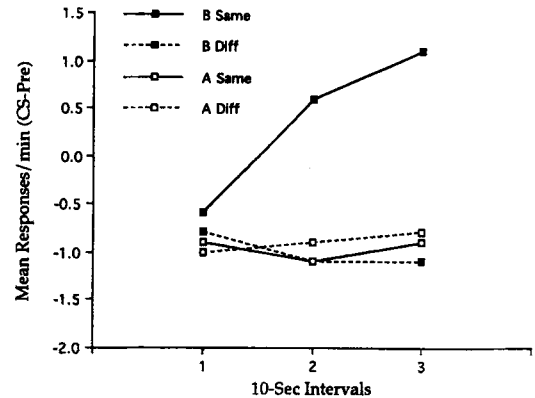


Figure 5. Mean instrumental response rates during the transfer tests of Experiment 2 broken down into successive 10-sec intervals within the CS.

data from the transfer tests were combined over the entire 30-sec interval in which the CS was presented. The same data were further segregated into three successive 10-sec intervals of the CS and are presented in Figure 5. This depiction of the data shows that the same versus different effect seen for stimulus B increased over time within the CS, presumably as the tendency to approach the magazine waned.

The statistical conclusions just described for the transfer test data as a whole also applied to the data broken down according to whether the ITI reinforcer was pellets or sucrose. The difference between same and different responses was very similar in the two subgroups for B [$F(1,14) = .01$], as well as for A [$F(1,14) = .08$].

The results from the present experiment indicate that outcome-selective effects of presenting ITI USs are obtained after conditioning has already developed. The magazine response data support this conclusion. Furthermore, the transfer data show that the expression of specific outcome knowledge also is selectively impaired by the introduction of outcomes in the ITI. These results imply that the outcome-selective effects of ITI USs are rather durable in this paradigm.

GENERAL DISCUSSION

The present experiments demonstrate that the introduction of intertrial USs has a selective, deleterious effect on some aspect of the associative process. This effect was observed not only during acquisition, but also for stimuli that had already been conditioned prior to the introduction of intertrial USs. These effects were observed "on-baseline" with the magazine response measure, as well as in transfer tests in which the stimuli were presented in an instrumental setting without reinforcement.

These data have several implications for how we understand the deleterious effects of ITI USs. Theories that have been proposed to account for contingency results can be classified, generally, as either performance or learning models. The former models assume that the

deleterious effects of ITI USSs result from interference with responding, whereas the latter models assume that the interference occurs with some aspect of the learning process. Performance models vary in terms of the use of overt and covert mechanisms responsible for the interference, and learning models vary in terms of the use of mechanisms that result in reduced trial processing of the CS, the US, or the CS-US episode. These different accounts will be discussed, in turn, in light of the present data.

The most straightforward performance account is an overt response competition account. The presence of USSs in the ITI can establish responses that directly compete with the responses normally evoked by a CS. Aside from a difficulty in imagining what the competing response might be in the present situation, where the CS and ITI USS both evoke magazine behaviors, the observation of outcome-selective effects of ITI USSs renders such an account additionally unlikely. Because the response forms to both CSs were very similar (i.e., both evoked magazine responses), the development of any competing response tendency in the ITI should have affected responding to both CSs.

Another, more covert performance account emphasizes the importance of comparator processes in determining responding. Models of this sort explain the interfering effects of ITI USSs by assuming that the expression of learning to a CS is an inverse function of the value conditioned to the context (Gibbon & Balsam, 1981; Miller & Schachtman, 1985). Such models could anticipate outcome-selective contingency effects like those reported here if it were assumed that context-CS comparisons were outcome specific. But problematic for these accounts is the demonstration of a lack of correlation between CS-elicited magazine responding and the current value of the (training/test) context (Durlach & Shane, 1993).

Additionally problematic for these accounts is the absence of a differential effect of ITI USSs on instrumental responding during the transfer tests in the present studies. If we assume that Pavlovian conditioned responses can be selectively affected by context, we might also assume that instrumentally conditioned responses should be similarly affected by context. In the present set of studies, this question could be examined by measuring instrumental responding in the prestimulus periods of the transfer tests. Recall that the two instrumental responses in these experiments were reinforced with different outcomes, one of which was also presented in the intertrial interval during the Pavlovian sessions. In the first experiment, the prestimulus means for the responses whose outcome previously had or had not occurred in the ITI were 3.7 and 3.7 responses/min, respectively. In the second experiment, the means were 4.1 and 3.1 responses/min, respectively. This difference was not statistically reliable [$F(1,15) = 1.45$]. Thus, the outcome-selective effects seen with stimulus-elicited magazine responses were not also seen with instrumental responses.

The present data also have implications for various learning accounts of the deleterious effects of ITI USSs. For example, some accounts are based on the idea that ITI USSs interfere with associative learning by disrupting the amount of CS processing that would occur on a trial. One notion is that a limited amount of processing can take place at any given time, and that pretrial USSs would compete with the CS for processing (Wagner, 1981). Such an account would not anticipate the selective effects reported here, since the disruptive effects of pretrial USSs on CS processing should not have been selective.

In addition to their effects on CS processing, intertrial USSs could result in interference with the processing of the entire CS-US episode, disrupting its "rehearsal" (see, e.g., Farley, 1987; Wagner, Rudy, & Whitlow, 1973). This idea can naturally apply to contingency procedures in which posttrial ITI USSs sometimes occur. However, it is not obvious from this perspective that the occurrence of a posttrial USS should be more disruptive when the trial and posttrial USSs are the same, as would be demanded by the present data (but see Holland, 1988).

There are several US processing accounts of contingency based on the notion that some process interferes with the ability of the US to be fully processed and therefore to support learning. The most obvious nonassociative mechanism of this sort is selective satiation. Although this mechanism cannot be ruled out in explaining the present data, its applicability is questioned for two reasons. First, only a small number of reinforcers were presented in each session, and these seemed to be readily consumed. Using similar parameters in an instrumental experiment, Williams (1989) found no evidence of satiation across the session. Second, selective satiation effects are typically small in magnitude (Colwill & Rescorla, 1985).

One associative mechanism in which ITI USSs might diminish the amount of US processing on a trial was described by Rescorla and Wagner (1972). According to these authors, the effectiveness of a US in supporting learning is diminished to the extent that stimuli on a trial already predict its occurrence. This assumption is used to explain the deleterious effects of ITI USSs on learning CS-US associations by assuming that contextual stimuli are associated with ITI USSs. Because contextual stimuli are also present during a CS-US trial, this association renders the US already predicted during the trial. Learning to the CS is said to be "blocked" by contextual stimuli that have already been associated with the US. An extension of these ideas to the present situation assumes only that conditioning and its loss be driven by a process that is more specific, say, in its sensory content, than has been assumed thus far.

At a more empirical level, it is valuable to compare the results reported here with those reported in contingency experiments with pigeons. The present data might be taken as being inconsistent with the conceptually similar work of Stanhope (1990). In her experiment, the selective effects of intertrial USSs interacted with the iden-

tivity of the intertrial US. It is noteworthy that the present studies, although obtaining a main effect, similarly observed this interaction with the magazine response measure. The transfer measure, being more specific in its ability to measure associations, did not reveal such an interaction. These data, taken together, would suggest that the effects observed on conditioned responses, be they keypecks or magazine approach, arise for reasons other than associative ones.

It is also of interest to compare the results from Experiment 2 with those from conceptually similar single US studies of autoshaping in pigeons. Lindblom and Jenkins (1981), Durlach (1986), and Rescorla (1989) have all observed substantial recovery during an extinction test of an autoshaped keypeck that had earlier been depressed by ITI USs. These authors concluded that the addition of ITI USs depressed previously conditioned responding through some means other than degradation of the association. There was no evidence of recovery of the degraded stimulus in Experiment 2 either with the magazine response measure or with the transfer measure over three choice tests in extinction. We might take those data as indicating that ITI USs selectively damaged an already established CS-US association (see also Durlach & Shane, 1993). If so, then the nature of the discrepancies between the two paradigms is not understood. Apparently, there is some mechanism that might serve to protect a CS from associative loss in the autoshaping procedure.

The present results are similar to those from studies exploring outcome-selective contingency effects in an instrumental task with rats. As mentioned earlier, Colwill and Rescorla (1986), Williams (1989), and Dickinson and Mulatero (1989) using instrumental choice tasks also found evidence for an outcome-selective contingency effect on already established responding. The similarities between these results and those from Experiment 2 suggest another way in which Pavlovian and instrumental processes converge (Mackintosh, 1983).

Independent of how the effects of ITI USs in various contingency paradigms are understood, the present data highlight the importance of sensory-specific processes in learning. These data not only illustrate that learning about specific features of the reinforcer takes place (see also Colwill & Rescorla, 1986; Delamater & LoLordo, 1991), but also support the claim that learning itself is driven by sensory-specific processes.

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Manuscript received November 2, 1993;
revision accepted for publication June 2, 1994.)