BRIEF REPORTS

Associative competition in operant conditioning: Blocking the response–reinforcer association

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Naive rats were trained to leverpress with a 30-sec delay-of-reinforcement contingency from the start of training. In Experiment 1, the delay interval for different groups of subjects included a signal in the first 5 sec, a signal in the last 5 sec, or no signal at any time. Rats with the signal at the start of the delay interval learned most rapidly. Rats with the signal at the end of the delay failed to learn. In Experiment 2, a choice procedure was used, in which each of two levers was associated with its own 30-sec delay of reinforcement. The delay for one lever included a 5-sec signal at the end of the delay. The delay for the second lever had no signal in its 30-sec delay. Preference was in favor of the lever without the signal in the delay interval. The results demonstrate that the acquisition of new response can be blocked in a manner analogous to the blocking of Pavlovian conditioning.

No empirical finding in the study of animal learning has been of greater theoretical importance than the phenomenon of blocking. When a stimulus (A) is paired with the unconditioned stimulus (US), and then A is compounded with a new stimulus (B) and this compound (AB) is also paired with the same US, subsequent tests involving B alone show a substantially decreased level of performance, relative to control conditions in which the AB compound is paired with the US without the prior training with A alone. The most influential interpretation of blocking, dating back to its initial report by Kamin (1968), has been based on the premise that temporal contiguity between a conditioned stimulus (CS) and US is not sufficient to produce an association between them. Instead, the CS must also provide information about the US's occurrence. Accordingly, the US is already predicted by the presence of stimulus A, so that the addition of stimulus B provides no further information and thus is not associated with the US. (But note that "nonassociative" interpretations of blocking have been proposed: e.g., Miller & Matzel, 1988.)

The idea that simple pairings of the CS and US are insufficient to produce learning has had major theoretical ramifications. It serves as the foundation principle of the well-known theory of learning of Rescorla and Wagner (1972) and has been extended to such human learning situations as category learning (e.g., Gluck & Bower, 1988) and contingency judgments (e.g., Vallée-Tourangeau, Baker, & Mercier, 1994). More generally, it poses important questions at the neurophysiological level, where the

theoretical analysis of learning has been predicated on the assumption that temporal contiguity is sufficient for learning to occur.

The great majority of research supporting the idea that temporal contiguity is not sufficient for learning to occur has been conducted with Pavlovian conditioning procedures, but the idea has also been supported in studies of instrumental/operant learning. In the first such experiment reported, Williams (1975) presented pigeons a 5-sec keylight with the contingency that a single peck during the keylight presentation caused the delivery of the food reinforcer 10 sec later. Different conditions were then defined by the events during the delay-of-reinforcement interval. Substantial responding occurred to the keylight when the delay interval was blank (i.e., had the same stimulus conditions as those for the intertrial interval), whereas the presentation of a second stimulus during the last few seconds of the interval greatly reduced the level of keylight responding. Subsequent investigations of the same general procedure (Williams, 1978, 1982; Williams, Preston, & de Kervor, 1990) have produced the same pattern of results. Apparently, therefore, contrary to traditional interpretations (Skinner, 1948), the temporal relation between the response and reinforcer is not sufficient to predict when a response–reinforcer association will be acquired.

The novelty of previous putative demonstrations of blocking of the response–reinforcer association has been questioned by the concern that the blocking effects seen are due to Pavlovian conditioning, not operant conditioning, because of the similarity of the procedure to auto-shaping. Arguments against this interpretation were presented by Williams (1978), based primarily on the finding that when the response contingency was removed, with

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food then delivered automatically at the end of the 10-sec delay regardless of the bird's behavior, the evidence for blocking was eliminated. That is, the level of keypecking was reduced for both conditions but the level of responding was slightly higher when the signal appeared during the delay interval. However, even that demonstration has been questioned as a sufficient basis for the claim that blocking of the response-reinforcer association has occurred, because operant contingencies may themselves affect the Pavlovian contingencies that are learned (Moore, 1973). Thus, if food is delivered only after a response has occurred, the animal must be attending to the keylight on those trials. Without a response contingency, in comparison, the subject may be attending to any number of stimulus features in the environment other than the CS.

The present study was undertaken in the attempt to avoid this alternative interpretation, in order that a more convincing demonstration of blocking of the response-reinforcer association might be provided. This new approach was inspired by the report of Lattal and Gleeson (1990) that experimentally naive subjects will acquire a new response even when the response-contingent reinforcer is delayed up to 30 sec. Given that acquisition is possible with such delayed reinforcement contingencies, it becomes feasible to determine how signals at the end of the delay interval affect the rate at which such acquisition occurs. In Experiment 1, three groups of rats were exposed to a 30-sec delay-of-reinforcement contingency with respect to leverpressing. For the control condition, no stimulus change occurred at any time during the delay interval. For the blocking condition, a 5-sec houselight was presented during the last 5 sec of the 30-sec delay. Technically speaking, this is an overshadowing procedure rather than a blocking procedure, because the signal was not pretrained prior to commencing the delay-of-reinforcement contingency. However, this distinction is purely semantic: Because of the differences in their temporal separations from food, the signal-food association was learned more rapidly than the response-reinforcer association. Thus, only a few learning trials were necessary to produce conditioning to the signal equivalent to that which would have occurred had prior training with the signal been provided. A third condition, marking, was also included (cf. Lieberman, McIntosh, & Thomas, 1979), in which the 5-sec houselight occurred during the first 5 sec of the delay interval. This condition was included to determine the extent to which the location of the houselight in the delay interval was a critical determinant of its effects.

EXPERIMENT 1

Method

Subjects. Twenty-four experimentally naive male albino Sprague-Dawley rats, ranging in age from 6 weeks to 4 months, were housed in individual wire-mesh cages in a colony room with a 14:10-h

light:dark cycle. Experimental sessions occurred during the light portion of the cycle, usually from 8 a.m. to 2 p.m. Water was freely available in the home cages, while food deprivation was maintained by allowing free access to lab chow for 2 h beginning approximately 5 min after the end of the experimental sessions.

Apparatus. Two identical experimental chambers were constructed, each from a Coulbourn modular shell that included a grid floor, two Plexiglas sidewalls, and ceiling, front, and rear walls of aluminum. The height of the interior chamber was approximately 29 cm; its width was 24 cm, and its depth was 31 cm. The interior chamber was enclosed within a larger exterior enclosure for sound insulation. Masking noise was provided by a ventilating fan.

Located in the center of the front panel, 3 cm above the floor, was the recessed food well, into which 45-mg Noyes pellets were presented from a Gerbrands pellet dispenser. On the left side of the front panel 15 cm above the floor was mounted a stainless steel retractable lever (Coulbourn Model E21-03), 3.7 cm wide, 0.3 cm thick, and extending 3.0 cm into the chamber when not in the retracted position. A minimum force of 0.25 N was required for operation. Mounted in the center of the front panel just below the ceiling was a houselight module (Coulbourn Model E11-01) equipped with a 28-V miniature bulb (no. 1828).

Procedure. Throughout training each experimental session was 30 min long. During the first two sessions, the lever was retracted from the chamber and free food was presented on a response-independent variable-time (VT) 60-sec schedule. On the third session, the lever was extended, the VT schedule was terminated, and food could be earned by leverpresses that were followed by a 30-sec delay-of-reinforcement interval, terminating with the delivery of the food pellet. Leverpresses while the delay timer was operating had no scheduled effect, so that the maximum number of reinforcers per session was 60. Training continued for 20 experimental sessions.

Different groups of subjects were defined by the stimuli during the delay interval. For the no-signal condition, no exteroceptive stimuli were presented during the delay. For the blocking condition, the houselight was presented during the last 5 sec of the delay, whereas for the marking condition, the houselight appeared during the first 5 sec of the delay.

Results

Figure 1 shows the mean number of obtained reinforcers for each of the three experimental groups. The number of reinforcers is used as the measure of the degree of conditioning, rather than response rate, because response rate was more variable across subjects. However, the effects to be reported also occurred for the response rate measure.

It is clear that the marking condition with the houselight signal at the beginning of the delay interval produced the most rapid acquisition, whereas the blocking condition, with the signal at the end of the interval, produced the slowest acquisition. Indeed, no evidence of acquisition occurred for the blocking condition. The control condition, in which no signal occurred at any time during the delay, was intermediate. Thus, the marking condition facilitated learning relative to the control, whereas the blocking condition retarded it.

These results were analyzed statistically with a two-way analysis of variance (ANOVA). The effect of experimental groups was significant [$F(2,21) = 15.6, p < .01$], as was the sessions variable [$F(9,189) = 13.8, p < .01$]. The interaction term was also significant [$F(18,189) =$

Figure 1. Mean number of reinforcers obtained per two-session block from the 30-sec delay-of-reinforcement contingency for each group in Experiment 1.

4.99, $p < .01$]. Analysis of simple effects showed that the sessions variable was significant for the marking and control conditions, indicating the acquisition of leverpressing with continued training. The sessions variable was not significant ($F < 1$) for the blocking condition, indicating that no acquisition occurred. Two-way comparisons with a Newman-Keuls test revealed that all three experimental groups were significantly different from each other.

A second approach to assessing the significance of signals in the delay interval is the number of subjects in each group that attained the learning criterion of a cumulative total of 100 reinforcers over the course of the 20 sessions of training. All 8 subjects in the marking condition reached that criterion, with a mean of 11.1 sessions. Only 4 of 8 subjects in the control condition attained the criterion, with those that did requiring a mean of 12.8 sessions. None of the subjects in the blocking condition attained the criterion.

Discussion

The present results provide a strong demonstration of complete blocking of response acquisition by signals appearing at the end of a delay-of-reinforcement interval when the reinforcer is contingent on the response. This result is similar to those of previous studies of blocking of the response-reinforcer association (cf. Williams,

1975, 1978, 1982; Williams et al., 1990), despite the fact that a very different experimental preparation was involved. Unlike the earlier studies, which used pigeons in discriminated operant procedures, here the object of the blocking effect was the acquisition of a novel instrumental response in a free-operant setting. The results thus provide prima facie evidence that the blocking of the response-reinforcer association is an empirical phenomenon of considerable generality and thus must be addressed for any general theory of blocking to be complete.

The present results also show that signals at the onset of the delay-of-reinforcement interval facilitate rather than retard the learning of new responses. This effect is reminiscent of the marking effect first reported by Lieberman et al. (1979), despite major differences in procedure. The results are also similar to those of Schaal and Branch (1988), who demonstrated that a brief stimulus change at the onset of an otherwise unsignaled delay interval maintained behavior at a level near that of behavior that was immediately reinforced.

The fact that marking occurs in the present response acquisition procedure suggests an alternative explanation of the results of the "blocking" condition in terms of response competition. The concept of marking implies that responses occurring just prior to the houselight signal should be remembered better at the time the reinforcer is delivered. Behaviors other than leverpresses may

have been adventitiously marked by the houselight, and thus were more greatly strengthened than such nonleverpressing behavior in the control condition in which the signal was not presented. Accordingly, the effect of the signal at the end of the delay interval may have been simply to increase the level of response competition. Such an explanation seems unlikely because any competing behavior should have extinguished when it occurred in the absence of the leverpress response, because food became available only when leverpressing had occurred. Nevertheless, Experiment 2 addressed this alternative explanation.

EXPERIMENT 2

One method of assessing the potential role of response competition caused by the marking of competing behaviors is to employ a choice procedure. To the extent that blocking effects occur in choice procedures in which one response has the signal in its delay of reinforcement while the alternative response has no signal, such blocking cannot be ascribed to response competition, because strengthening competing responses should reduce both choice alternatives equally. If blocking is found in a choice procedure, it also rules out the possibility that the signal preceding the reinforcer has altered the properties of the background cues (e.g., by reducing their ability to produce arousal). Any change in the status of the background cues presumably should affect both response alternatives equally, given that they share the same background. Experiment 2 thus extended the procedure used in Experiment 1 to include two separate response levers, each of which produced a food pellet after a 30-sec delay interval. The two responses differed only in terms of whether the signal occurred during the last 5 sec of the delay interval.

Method

Subjects. Twenty-two experimentally naive female Sprague-Dawley rats served as subjects. The subjects were maintained as described for Experiment 1.

Apparatus. A standard two-lever rat chamber, different from that used in Experiment 1, with glass sidewalls, sheet metal ceiling, front walls, and rear walls, and a grid floor, was housed inside a sound-attenuating larger chamber equipped with a ventilating fan. The interior of the chamber was 30.5 cm wide $\times$ 20.3 cm high $\times$ 22.9 cm long. Two retractable levers (BRS/LVE Model RRL-015), which protruded 1.5 cm into the chamber when extended and which required a minimum force of 0.3 N for depression, were mounted on the front wall of the chamber, spaced 9 cm apart measured from side to side. The only feedback for a leverpress was the sound of the microswitch inside the lever housing. Directly between, and 6.5 cm below, the levers was a food receptacle in which could be dropped 45-mg Noyes pellets (improved Formula A) that served as the reinforcer. Between, and 3.3 cm above, the levers was a 28-V pilot light, covered by a glass translucent cover.

Procedure. On the first session of training, subjects were placed in the experimental chamber without prior training, but with three to five food pellets placed in the pellet receptacle and both response levers extended into the chamber. The experimental contingencies used for the entire experiment were in effect from the onset of training. Responses to either the left or the right lever initiated a 30-sec

delay timer that terminated with the delivery of food. During this delay interval, additional responses to either lever had no scheduled effect. For the delay interval produced by one lever, a 5-sec presentation of the houselight occurred during the last 5 sec of the interval; for the delay interval produced by the alternative lever, no signal was presented during the delay. The subjects were randomly assigned to two groups, one with the signal following responses to the right lever, and a second with the signal following responses to the left lever. Experimental sessions continued until 50 reinforcers were obtained, or until 45 min had elapsed, whichever came first. Training continued for 25 sessions.

Results

Figure 2 shows the mean percentage of the total reinforcers that were obtained by responses to the right lever. At the start of training, both experimental conditions had a significant bias toward the right lever, which resulted in approximately 70% of the choices to the right lever regardless of which delay interval contained the signal. When the signal appeared only during the delay contingent on responses to the left lever, choices of the right lever then increased over the course of the 20 sessions of training; when the signal appeared only during the delay contingent on response to the right lever, choices of the right lever decreased over training.

These results were analyzed with a two-way ANOVA. The effect of the location of the signal was significant [$F(1,20) = 7.54, p < .05$]. The effect of sessions of training was not significant [$F(4,80) = 1.67, p > .05$]. The interaction between the two variables was also significant [$F(4,80) = 7.06, p < .01$]. Thus, a significant preference developed over training for the lever without the signal in its delay interval.

Discussion

The results of Experiment 2 show that preference for a choice alternative is strongly reduced by a signal occurring during the last portion of a delay-of-reinforcement interval prior to the reinforcer contingent on that response. To the extent that the results of Experiments 1 and 2 depend on the same mechanisms, the demonstration of blocking in the choice procedure used in Experiment 2 excludes any interpretation of the effect in terms of response competition, or in terms of changes in the motivational properties of the background stimuli, because both such effects should have been equated for the two choice alternatives.

It is important to recognize that the results obtained in both Experiments 1 and 2 are in the opposite direction from that anticipated on the basis of traditional conceptions of delay of reinforcement. The signal presumably possessed conditioned reinforcement properties because of its temporal contiguity with food and thus should have functionally shortened the delay interval in which it appeared. Consequently, a slight preference should have occurred for the alternative with the signal during the last 5 sec of the 30-sec delay, because its delay of reinforcement was only 25 sec. The strong effect in the opposite direction implies that the signal in the delay interval some-

Figure 2. The percentage of the total number of reinforcers that was obtained by choices of the right lever in Experiment 2. One group of subjects had a 5-sec signal in the delay interval following a choice of the right lever; the second group had the signal in the delay interval following a choice of the left lever.

how interfered with the ability of the delayed reinforcer to strengthen choice responding, the most plausible interpretation of this interference being that the signal competed with the response for association with the reinforcer.

The procedure used here to demonstrate blocking of the response–reinforcer association differs from the usual Pavlovian study of blocking in two ways. The first is the use of serial stimulus compounds rather than simultaneous compounds. Here the stimulus with prior conditioning that prevented the acquisition of instrumental responding occurred after the target event (the response) had already occurred. By contrast, in Pavlovian procedures, the pretrained stimulus is typically presented simultaneously with the target (a second stimulus). However, blocking with serial stimulus compounds has been demonstrated with several different Pavlovian procedures (Gibbs, Kehoe, & Gormezano, 1991, Experiment 3; Kohler & Ayres, 1982; Pearce, Nicholas, & Dickinson, 1981, Experiment 4). That is, when a trace conditioning procedure is used, inserting a second stimulus between the target CS and the US reduces acquisition to the target CS. It should be noted that this finding is the opposite to that which would be expected on the basis of second-order conditioning, just as the present report is contrary to the expected effects of conditioned reinforcement. In

both cases, whether the procedure produces blocking or second-order conditioning (or conditioned reinforcement) depends critically on the temporal relationships among the elements of the training situation (for a discussion of this issue, see Gibbs et al., 1991, and Williams, 1982). In general, the optimal procedure for producing blocking rather than conditioned reinforcement is that used in the present study, in which the interspersed stimulus is temporally distant from the target event (here a response) but contiguous with the reinforcer. In any event, the present findings are consistent with previous studies with Pavlovian conditioning in showing that blocking can be obtained with sequentially presented associative elements.

The second difference between the present procedure and Pavlovian studies of blocking was the use of a response contingency determining the delivery of the reinforcer. In Pavlovian procedures, the delivery of the US (the reinforcer) occurs regardless of the animal's behavior, so that the same number of US presentations is presented regardless of whether blocking does or does not occur. In the present study, by contrast, the food reinforcers were presented only when the operant response had been emitted; if blocking occurred, food was not delivered. The presence of the response–reinforcer contin-

gency provides a strong incentive for responding to occur, assuming that the response-reinforcer association has been acquired. Thus, accounts of blocking in terms of performance rules, rather than in terms of an actual failure of acquisition (e.g., Miller & Matzel, 1988), can be applied only with considerable difficulty. In that sense, the occurrence of blocking of response-reinforcer associations provides significant support for the inadequacy of mere temporal relationships to predict when learning will occur.

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(Manuscript received April 29, 1998;
revision accepted for publication December 18, 1998.)