THE BLOCKING OF REINFORCEMENT CONTROL¹

BEN A. WILLIAMS

UNIVERSITY OF CALIFORNIA, SAN DIEGO

Two experiments were conducted to extend the blocking effect to the reinforcement of a response. A delayed reinforcement contingency was presented to subjects with or without a previously pretrained response available during the delay interval. The interpolated response had no scheduled effect on delivery of the reinforcer, but its availability reduced strengthening of the initial response, which completely extinguished for some subjects. The results were interpreted as support for blocking as a fundamental principle of behavior, and as evidence against the principle of reinforcement being stated solely in terms of temporal proximity between response and reinforcer.

Key words: blocking, principle of reinforcement, delay of reinforcement, temporal contiguity, predictiveness, information, pigeons

Investigations of the conditions defining when behavior is strengthened (or selected) by reinforcement and of the conditions defining the occurrence of stimulus control over behavior have grown increasingly separate. Perhaps because of the emphasis on operants as *emitted* behavior, with no necessary eliciting stimulus, response strengthening and stimulus control have been assumed, at least implicitly, to be independent processes, which may obey different laws of conditioning. Such a separation is to be contrasted with the Thorndikean law of effect, where the unit of learning was the S-R *connection*, and response strengthening and stimulus control were totally interdependent.

The effect of the Skinnerian rejection of the S-R connection is nowhere more evident than in the treatment of temporal contiguity as a condition for learning. Until recent challenges (*e.g.*, Baum, 1973; Bloomfield, 1972), temporal contiguity between response and reinforcer has been almost universally accepted as the key ingredient of the principle of reinforcement. In the words of Skinner (1948), "... conditioning takes place presumably because of the temporal relation only, expressed

in terms of the order and proximity of response and reinforcement." In contrast, there never has been universal acceptance of temporal contiguity's role for stimulus control. The need for differential reinforcement (*e.g.*, Jenkins and Harrison, 1960) and the apparent involvement of selective attention (*e.g.*, Reynolds, 1961) both have argued, persuasively to some, that temporal contiguity between stimulus and reinforcement is not a sufficient condition for stimulus control.

More recent research has shown clearly that, indeed, temporal contiguity is not sufficient (*cf.* Honig, 1970). Perhaps the most definitive demonstration of stimuli not gaining control even when indefinitely paired with reinforcement is the "blocking effect" (*cf.* Kamin, 1968; 1969). The typical procedure for producing blocking is to pair some compound stimulus, *AB*, with reinforcement. Normally both elements gain control, as shown when they are tested separately. When one of the elements *A* is pretrained alone, however, stimulus control by the other element *B* occurs much less during compound *AB* training. Thus, the pretraining of *A* "blocks" control by *B*.

The question raised by demonstrations such as blocking is whether similar functional relations can be shown for the operant strengthening of a response by reinforcement. To the extent that stimulus control and response strengthening obey similar laws, some more unitary conception of learning would seem required. The present experiments addressed

¹This research was supported by USPHS grant MH 25202-01 and NSF grant GB-42887 to the University of California. Reprints may be obtained from the author, Department of Psychology, University of California, San Diego, P. O. Box 109, La Jolla, California 92037. The author thanks George S. Reynolds for the loan of equipment to conduct Experiment 2.

this issue by extending the blocking effect to a response-reinforcer relation. A contingency was arranged between a response and reinforcer in a situation where an alternative response was available that previously was associated with the reinforcer. The opportunity for the two responses was arranged sequentially. First came the response to be conditioned, and then the previously associated response. At issue was whether the presence of the previously associated response during the delay between the initial response and reinforcer blocked the strengthening of the initial response.

EXPERIMENT 1

Subjects

Twelve experimentally naive mixed-breed pigeons were maintained at 80% of their free-feeding body weights.

Apparatus

Two identical chambers with interior dimension of 28 by 30 by 38 cm were constructed from styrofoam picnic cases and placed in larger wooden boxes. Two translucent pigeon keys, each 2.5 cm in diameter, were located 23 cm above the floor, and 10 cm apart, center to center. Each key required at least 20 g force (0.20 N) for operation. The left key could be illuminated with red light, the right key with green light. Between and 8.0 cm below the keys was the grain hopper, which was activated for reinforcement. The two chambers were located in a completely darkened room, isolated from the scheduling equipment in an adjoining room.

Procedure

Pretraining. After learning to peck the right-green response key, all subjects were trained in the next two to three sessions to peck on a fixed-ratio 25 reinforcement schedule (FR 25). They were then given four additional sessions with the FR 25 schedule. Throughout pretraining, the right-green key was illuminated continuously and the left-red key was darkened and inoperative. All sessions terminated after 50 reinforcements. Six subjects were then assigned to each of two experimental conditions.

R + G condition. After pretraining, all sessions were divided into 50 discrete trials. A trial began with illumination of the left-red

key for 5 sec, followed by 5 sec of darkness, followed by illumination of the right-green key for 4 sec, followed by a 3.0-sec reinforcer if at least one peck had occurred on the left-red key while illuminated. Responses to the right-green key had no scheduled effect. In addition to the reinforcement obtained through pecking, response-independent grain delivery at the green-key offset was scheduled on one-third of the trials on a quasirandom basis. The additional reinforcement was included to ensure that the green-key responding would be maintained even if red-key responding extinguished. Trials were separated by a 50-sec intertrial interval, during which time the chamber was dark.

R-only condition. The procedure for the six control subjects was similar except that the right-green key was not illuminated during the last 4 sec of the delay interval. Their trials were composed of 5 sec of left-red key illumination, 9 sec of darkness, and then reinforcement if a red-key response had occurred. As with the blocking condition, response-independent reinforcement was scheduled on one-third of the trials at the end of the 9.0-sec delay.

Reversal of conditions. After 10 sessions under the above procedures, the conditions for the two groups were reversed, and 10 additional sessions were presented.

RESULTS

Figure 1 presents the mean percentage of trials on which reinforcement was obtained by a response to the left-red key. Subjects with the interpolated green key responded to the red key less often. To assess the effect statistically, the data were subjected to a two-way analysis of variance. The blocks produced a significant effect ($F_{9,90} = 5.40$, $p < 0.01$), but the F-value for the treatment effect only approached significance ($F_{1,10} = 4.65$, $0.10 > p > 0.05$). The blocks X treatment interaction was significant, however ($F_{9,90} = 2.72$, $p < 0.01$), indicating that the two groups significantly diverged as training continued.

The second portion of Figure 1 shows the effect of reversing the conditions. Subjects initially trained on the R-only condition continued to respond to the red key with only a slight decrement. Once reinforcement control was established, therefore, addition of the interpolated response generally did not abolish

Fig. 1. Mean percentage of trials on which at least one peck occurred on the initial red key.

the control, at least with the number of sessions used. In contrast, subjects initially trained on the R + G condition responded substantially more when switched to the R-only condition. The failure of complete

recovery is not depicted adequately by the group mean because two subjects never responded after the conditions were reversed.

Figure 2 shows the individual data for subjects trained initially on the R-only condition and then switched to R + G. During initial training, five of the six subjects gradually increased responding to the red key; Subject 33 never developed any consistent responding throughout the 10 sessions of training. A noteworthy observation is the data of Subject 40, whose responding decreased toward the end of the R-only training. This decrease with continued training under delayed reinforcement has been noted on several occasions with the present procedure and is consistent with the delay-of-reinforcement literature (*cf.* Logan, 1960).

The effects of shifting from R-only to R + G are shown in the second portion of Figure 2, which presents each response separately. Three subjects (35, 18, 60) continued to respond to

Fig. 2. Percentage of trials with at least one peck on the initial red key for subjects trained on the R-only condition and switched to R + G.

the red key without decrement; Subjects 37 and 40 showed a small decrement, and Subject 33 once again did not develop any consistent responding. Noteworthy is that maintenance of the red-key response occurred in conjunction with resumption of green-key responding. The only exception was Subject 18, which never responded to the green key after the switch in conditions, in spite of its pre-training of that response, and also in spite of the green key's close temporal association with reinforcement.

Figure 3 shows the variety of performances for subjects initially trained on R + G. Four of the six subjects had essentially no red-key responding by the end of the initial phase of training. Three of these continued to respond to the green key, while the fourth, Subject 16, ceased responding. The two remaining subjects that did respond to the red key also continued to respond to the interpolated green key.

The second portion of Figure 3 shows the results of shifting to the R-only condition. By the end of that training, four of the six subjects responded consistently to the red key. The remaining subjects never responded to the red key and consequently that behavior was never reinforced.

DISCUSSION

Experiment 1 indicated that reinforcement control in a delayed reinforcement situation is in some measure a function of the behavior in the delay interval. Subjects that had the delay interval filled with darkness responded consistently more than those that had available a response previously associated with reinforcement. With the second response available, in fact, responding normally controlled by the delayed reinforcement contingency ceased completely for some subjects. A tentative conclusion, therefore, is that temporal contiguity between response and reinforcer is

Fig. 3. Percentage of trials with at least one peck on the initial red key for subjects trained on R + G and switched to R-only.

not a sufficient condition for the occurrence of reinforcement. Apparently, reinforcement control over a response can be blocked, just as stimulus control previously has been shown to be blocked.

Explanations other than blocking are of course possible. The simple occurrence of the response during the delay interval is correlated with several other variables, including differences in illumination, response competition, *etc.* The primary datum needed to establish blocking as the sole explanation of the above data is an inverse functional relation between the strength of the response interpolated in the delay interval and the degree of strengthening of the first response. Kamin (1969) reported such a relation for the blocking of stimulus control. That is, the degree of control acquired by element *B* during compound *AB* training is an inverse function of the amount of control acquired by element *A* during pretraining. Experiment 2 attempted to establish a similar result for the reinforcement control over behavior.

EXPERIMENT 2

The rationale of this experiment was to determine the level of initial-key response as a function of the degree of association of the interpolated response with reinforcement. The manipulation of this association was accomplished by presenting two types of conditioning trials. One type was that in Experiment 1: first key, delay, second key, and then reinforcement if a response occurred to the first key. The second type presented the second key alone but with different reinforcement contingencies. For one experimental condition, responses to the second key were reinforced, whereas for a second they were extinguished. Two additional conditions were also run to control for the effects of reward *versus* extinction *per se*.

Subjects

Sixteen experimentally naive White Carneau pigeons were maintained at 80% of their free-feeding body weights.

Apparatus

Two standard chambers included an inner Plexiglas chamber, 30.5 cm in all dimensions, attached to a metal panel, and enclosed in a

larger chamber. On the metal panels were mounted two Gerbrands pigeon keys, 1.9 cm in diameter, which required a force of 0.10 to 0.12 N for operation. The keys were mounted 15 cm apart center to center for chamber 1, and 12 cm apart for chamber 2. The keys were illuminated with two 7.5-W Christmas-tree light bulbs for chamber 1, and with two 28-V jewel lights for chamber 2. For both chambers, the food magazine was located directly between and 12 cm below the two keys. House-lights were located in the upper left-hand corners of the two chambers.

Procedure

All subjects were first trained with an auto-shaping procedure using the right-red response key (*cf.* Brown and Jenkins, 1968). The key was illuminated for 5 sec, followed by 3 sec of food reinforcement. Trials were separated by a variable intertrial interval (mean = 50 sec) ranging from 20 to 110 sec. All subjects were trained under these conditions until the first session in which an autoshaped response occurred, and were then given one additional session. All sessions terminated after 50 trials.

All subjects were then presented three sessions of training with the left-green key continuously illuminated and the right-red key darkened and inoperative. In the first session, all pecks were reinforced; in the second and third sessions, pecking was reinforced on a VI 15-sec schedule. Sessions terminated after 50 reinforcements.

The subjects were then exposed to four experimental conditions, each of which involved two types of conditioning trials. One-half of the trials for all conditions consisted of presentations of the left-green key alone for 4 sec. For Conditions 1 and 3, reinforcement followed the offset of the green key if at least one peck occurred during its presentation. For Conditions 2 and 4, green-key responses were never reinforced. On the other half of the trials, Conditions 1 and 2 involved the R + G procedure of Experiment 1: the red key was illuminated for 5 sec, followed by 5 sec of delay, 4 sec of green-key illumination, and then food presentation if at least one peck had occurred on the red key. For Conditions 3 and 4, the second type of trial involved the R-only procedure of Experiment 1: the right-red key was illuminated for 5 sec, followed by 9 sec of delay, and then reinforcement if at least one

Table 1
Training Conditions for the Four Procedures

Condition	Trial Type	
	A	B
1	R + G	G → S ^R
2	R + G	G → EXT
3	R-only	G → S ^R
4	R-only	G → EXT

peck had occurred. Table 1 summarizes the procedures. The two types of trials alternated quasirandomly. Twenty-five trials of each type were presented each session, with the same intertrial intervals as used in autoshaping (mean = 50 sec). A houselight was used throughout all phases of training.

Training was divided into three phases, as defined by the assignment of subjects to experimental conditions. The different phases were separated by a single retraining session with the right-red key alone, to ensure that responding occurred to that key at the beginning of an experimental condition. The first five to 10 trials during the retraining sessions involved the autoshaping procedure described above. The remaining 40 to 45 trials used a delayed reinforcement procedure where the red key was illuminated for 5 sec followed by a 3-sec delay, and then reinforcement if at least one peck had occurred. Training during each phase was planned to continue for 10 sessions. After the first 10 sessions of Phase 1

(hereafter designated Phase 1A), however, it became apparent that responding to the red key was highly variable across subjects. To reduce the variability, all subjects were presented one session of the red-key retraining procedure just described, and then were returned to their original training conditions for 10 additional sessions (Phase 1B). Phases 2 and 3 each involved only 10 sessions. Table 2 summarizes the assignment of subjects to conditions for each phase of training.

RESULTS

Figure 4 shows the mean percentage of red-key responding for the last two sessions of each phase of training. The different phases correspond to each new assignment of subjects to conditions. The primary comparison of interest is that between Conditions 1 and 2, which both received the R + G trials. As can be seen, Condition 1 produced a consistently lower probability of red-key responding for all phases of training. Separate t-tests among conditions were conducted on Phase 1A and the combined Phases 1B, 2, and 3. Both differences were statistically significant (Phase 1A: $t = 2.88$, 6 df., $p < 0.05$; Phases 1B, 2, and 3: $t = 2.32$, 22 df., $p < 0.05$).

To substantiate that the difference between Conditions 1 and 2 was due to the differential effects of presenting the green key in the delay interval, and not simply to the differential green-key contingency when it was presented

Table 2
Percentage of trials with a response to the red key during the last two sessions of each condition.

Subject	Phase 1			Phase 2		Phase 3	
	Condition	% (1A)	% (1B)	Condition	%	Condition	%
1	1	8	16	1	28	4	70
18	1	90	98	2	98	3	100
22	1	4	82	3	80	2	82
13	1	2	40	4	64	3	96
6	2	86	90	1	56	4	82
15	2	96	58	2	76	1	40
10	2	82	82	3	96	3	80
20	2	88	94	4	100	1	98
9	3	0	100	1	96	1	58
3	3	0	94	2	90	2	84
11	3	82	68	3	68	4	90
5	3	12	74	4	96	4	86
7	4	84	84	1	2	2	70
25	4	0	82	2	76	3	98
21	4	66	90	3	62	1	90
17	4	96	82	4	80	2	92

alone, the control Conditions 3 and 4 were also run. These two conditions received R-only trials instead of R + G trials, but with different contingencies associated with the G-alone trials. Any difference between Conditions 3 and 4 would thus be due to the effects of reward *versus* extinction associated with green, quite apart from its presentation during the delay-of-reinforcement interval. Figure 4 shows an effect for Phase 1A but no difference for any of the remaining phases of training. The difference for Phase 1A was not statistically significant ($t = 1.31$, 6 df., $p > 0.05$).

The small amount of Condition-3 responding during Phase 1A is noteworthy because it is similar to effects often found with the present procedure when subjects are transferred abruptly to a long delay of reinforcement. That is, subjects typically show an initial reduction of responding, which may or may not recover. In the present case, three of the four subjects had stopped responding during the first three to four sessions, and their responding never recovered. After retraining on the 3-sec delayed reinforcement procedure before the start of Phase 1B, however, all subjects continued to respond consistently. Apparently, some minimal training on a short delay of reinforcement is necessary to maintain behavior under longer delays. Observation suggested that food-magazine orientation produced blocking analogous to that produced by the explicitly interpolated response.

Because the difference between Conditions 1 and 2 was due to the differential history of the interpolated green response, of particular interest is the degree of green-key responding

on the R + G trials. Table 3 shows the mean rate of responding to the interpolated green key for both conditions during each phase of training. Little difference between the conditions occurred for either part of Phase 1, in spite of a significant difference for red-key responding. The high level of green-key responding for Condition 2 is somewhat surprising, since little responding occurred to the green key when it was presented alone. Responding to the green key on R + G trials did decrease during Phases 2 and 3, but this was due primarily to some subjects not developing responding upon transfer to that condition. In particular, subjects transferred from Condition 4 to Condition 2 never developed the interpolated responding in spite of the green key being followed consistently by the reinforcer. It is nonetheless clear from Table 3 that the degree of interpolated responding was not a critical determinant of the difference between the two conditions.

The individual subject data are shown in Table 2 and Figure 5. Table 2 shows the percentage of red-key trials with at least one response during the last two sessions of each experimental condition. Of primary interest is the pattern of variability for subjects trained under Condition 1. Whereas the performance of most subjects was reduced during that condition, performance for some subjects was maintained. The two classes of obtained behavior do not appear to be due to random variability, but instead are consistent with the results of Experiment 1. Namely, the subjects with maintained performance under the R + G condition also maintained their performance under all other conditions as well.

Figure 5 shows the individual subject data for all subjects transferred between Conditions 1 and 2 without any other condition interspersed between. For all subjects, the mean level of red-key responding across sessions was less for Condition 1. The variability across sessions was also greater for Condition 1.

Fig. 4. Mean percentage of trials on which at least one peck occurred on the initial red key in the last two sessions of each phase of training.

Table 3

Mean rate of responding (responses per second) to the interspersed green key, for R + G trials, for the last two sessions of each phase of training.

	1A	1B	2	3
Condition 1	2.17	2.65	3.27	1.96
Condition 2	2.58	2.78	1.94	0.69

Fig. 5. Individual data for R + G trials for subjects transferred directly between Conditions 1 and 2. Subjects in the left panel were transferred from Condition 2 to Condition 1; subjects in the right panel were transferred from Condition 1 to Condition 2.

Of particular interest is Subject 7. Its training preceding Condition 1 was Condition 4, during which all green-key responding had extinguished. At the start of Condition 1, therefore, the subject was responding to the red key but not to the green key, either during the R + G trials or during trials when G was presented alone. In Session 3, response-independent reinforcement was given following the G-alone trials for the first 10 trials of the session. Responding to G-alone immediately developed and then transferred to the R + G trials. The development of the interpolated responding resulted, in turn, in the rapid decline of red-key responding, which persisted until the end of training.

DISCUSSION

The results demonstrate that the blocking effects were due to the history of reinforcement of the response interpolated in the delay-of-reinforcement interval. Although Conditions 1 and 2 involved identical reinforcement contingencies with respect to the initial red key, and also involved identical opportunities for interpolated responding, blocking occurred only for Condition 1, in which the interpolated response was separately associated with reinforcement outside of the R + G trials. Of major significance in understanding the mechanism of blocking is the fact that the actual occurrence of interpolated responding for the two conditions was not systematically different. Such a finding establishes that the association of the interpolated response with reinforcement, not simply its occurrence in the delay-

of-reinforcement interval, is the critical variable in producing blocking. Such a result also excludes alternative explanations in terms of simpler mechanisms involving sequences of stimuli, illumination during the delay interval, response competition, *etc.*

A question raised by the present results is whether they require explanatory principles different from those postulated for the blocking of stimulus control. Two aspects of this issue should be separated. The first concerns the role of the instrumental contingency of reinforcement for the initial red key. Much recent emphasis has been given to the notion that pigeon's key pecking has many classical conditioning components (*e.g.*, Moore, 1973), and perhaps the blocking effect obtained here has little generality for other instrumental learning situations. Blocking effects, however, are not restricted to classical conditioning procedures, but instead have been obtained in a variety of different procedures with different subjects (*cf.* Honig, 1970). Also, the present results do seem to depend upon the use of an instrumental contingency for the initial red key. Unpublished research with the procedure used in Experiment 1, but with all reinforcement delivered noncontingently, generally has not been the same, mainly because the behavior to the initial red key is not maintained by the control condition using delayed reinforcement (the R-only procedure of Experiment 1).

The second issue concerning the mechanism of the effect is whether the critical feature for blocking is the interpolated response or the keylight stimulus that previously has been associated with reinforcement. This question may be impossible to answer, because any response must be directed toward some feature of the apparatus, so that at least some stimulus properties also must become associated with reinforcement. Conversely, the presentation of a stimulus associated with reinforcement is likely to elicit some responding. The question becomes even less meaningful when it is considered that the response must itself possess stimulus properties, and that many investigators have argued that instrumental conditioning is simply the association of response-produced stimuli with the reinforcer (*e.g.*, Bindra, 1972). Such a possibility suggests that the blocking effects obtained here and those found in stimulus control are interchangeable.

The present results nonetheless differ from previous demonstrations of blocking in several important respects. Blocking research using stimulus-control procedures generally has simultaneously compounded stimulus elements where one element of the compound previously had been paired with reinforcement. In contrast, the present study sequentially presented the elements with a 5-sec delay period between them. Secondly, stimulus-control research has demonstrated blocking only with situations where the obtained rate of reinforcement was unaffected by blocking. In the present case, however, blocking was obtained in spite of the consequent reduction in rate of reinforcement. Such differences indicate that blocking is of central importance in many learning situations, both classical and operant, and indeed may be one of the most fundamental of learning phenomena.

Perhaps the most important aspect of the present results is their implication for a general theory of conditioning. Any statement of the law-of-effect solely in terms of temporal contiguity (*e.g.*, Herrnstein, 1966; Skinner, 1948) is clearly inadequate, but less obvious is what direction any additional, or alternative, principle should take. One approach, consistent with considerable recent theoretical speculation (*cf.* Bloomfield, 1972), is to emphasize that learning occurs only when the response "predicts" the occurrence of the reinforcer. The difficulty with such an approach is that it is imprecise. Unless the conditions that determine predictiveness are clearly specified (*e.g.*, temporal boundaries), the concept can be used to explain, but not predict, virtually any conditioning result. In addition, at least some versions of the notion (*e.g.*, Baum, 1973) commit the experimenter to a "molar" analysis of conditioning, rather than the delineation of moment-by-moment changes in response strength.

An alternative approach to the present results is the conditioning model of Rescorla and Wagner (1972). The model was inspired by several different findings in the realm of classical conditioning, including blocking, but appears generally applicable to the stimulus control of operant behavior as well (*cf.* Williams, 1973). The question is whether it is also applicable to the operant strengthening of a response. According to the Rescorla-Wagner model, each reinforcing event (US)

has some asymptotic amount of conditioning associated with it, which will be distributed across the various stimuli that precede it. Events then paired with the US become conditioned only if the sum of the existing conditioning to all of the stimuli in the situation is different from the asymptotic conditioning possible. If the sum is less, excitatory conditioning will occur; if the sum is more, inhibitory conditioning will occur.

The main features of the Rescorla-Wagner model appear directly applicable to the present results. The pretraining of the interpolated response presumably caused most of the asymptotic response strength possible to be acquired. Later exposure of the second response to delayed reinforcement was therefore less effective because little further conditioning remained possible.

A total application of the model to the present data is not without difficulty, however. One major obstacle is to define "asymptotic response strength possible" in an operant situation. A variety of data (*cf.* Herrnstein, 1970) indicates that particular rates of reinforcement are not uniquely associated with particular asymptotic response levels, but rather the asymptotic level is a relative function of the "context of reinforcement". A related problem concerns the assessment of the "sum of the existing response strengths". For two subjects in Experiment 1, the interpolated response occurred regularly and yet was accompanied by substantial changes in the probability of the initial response. To the extent that conditioning of the first response was attributable to the degree of response strength of the second response, therefore, some assessment of that response strength, other than rate of pecking, must be used. Similarly, in Experiment 2, differences in the degree of blocking (Condition 1 *versus* Condition 2) occurred in spite of little difference in the degree of interpolated responding in the delay-of-reinforcement interval. Instead, blocking was a function of whether the interspersed response was reinforced on separate trials where the initial response was not available. Such results argue for some intervening concept such as "level of associability", rather than tying an analysis of the blocking effect to direct measures of response rate.

Regardless of the success of deriving the present results from a general model of learn-

ing, the experiments described above have implications for several areas of research. One is the study of delay of reinforcement. The degree of response strengthening was not an absolute function of temporal proximity, but of the occurrence of other responses during the delay interval. A possible implication is that no invariant delay-of-reinforcement gradient exists. The effect of a particular delay may instead depend on the nature of the situation, *i.e.*, upon the likelihood of intervening responses developing during the delay interval. Parameters such as size of the experimental chamber, illumination, *etc.*, should be expected to be of critical significance.

Several findings in the delay-of-reinforcement literature support the present treatment. One common result is that the acquisition function with delayed reinforcement is nonmonotonic (*cf.* Logan, 1960). Such a result could be accounted for if, as conditioning progresses, the strength of intervening behavior increases. More direct evidence comes from a recent study of T-maze learning in rats (Lett, 1975), which found that learning occurred even with long delays between the response and reinforcer only if the rats were removed from the apparatus during the delay. In addition, learning was retarded as a function of the time the subjects were left in the apparatus before removal.

The preceding analysis seems in conflict with at least one study of delayed reinforcement effects. Using a concurrent-chain procedure, Neuringer (1969) compared the effects of delayed reinforcement *versus* fixed-interval reinforcement where the two types of delay intervals were equated. According to the present analysis, one should presumably expect that the addition of the fixed-interval response requirement would reduce preference. To the contrary, Neuringer's subjects were indifferent. While Neuringer's delay values and other procedural parameters were perhaps too different to warrant comparison with the present study, one resolution of the discrepancy is that the effective variable in Neuringer's study was not delay of reinforcement but the relative conditioned reinforcement values of the stimulus change cueing the entry into the second link.

The present results also bear on the analysis of chained schedules of reinforcement. When chained schedules have been compared

with the corresponding tandem controls, the different behavior produced by the two schedules has been interpreted in terms of the roles of conditioned reinforcement and stimulus control. The present results imply that blocking is another factor involved in the comparison. Namely, the reinforcement of responding in early links of the chained schedule may be blocked because the intervening later links are highly associated with reinforcement, thereby explaining the general failure to maintain responding in the initial link with chained schedules having several components.

REFERENCES

- Baum, W. The correlation-based law of effect. *Journal of the Experimental Analysis of Behavior*, 1973, 20, 137-153.
- Bindra, D. A unified account of classical conditioning and operant training. In A. Black and W. Prokasy (Eds.), *Classical conditioning II: current theory and research*. New York: Appleton-Century-Crofts, 1972. Pp. 453-481.
- Bloomfield, T. M. Reinforcement schedules: contingency or contiguity? In R. Gilbert and J. Millenson (Eds.), *Reinforcement: behavioral analysis*. New York: Academic Press, 1972. Pp. 165-208.
- Brown, P. L. and Jenkins, H. M. Auto-shaping of the pigeon's key-peck. *Journal of the Experimental Analysis of Behavior*, 1968, 11, 1-8.
- Herrnstein, R. J. Superstition: a corollary of the principles of operant conditioning. In W. Honig (Ed.), *Operant behavior: areas of research and application*. New York: Appleton-Century-Crofts, 1966. Pp. 33-51.
- Herrnstein, R. J. On the law of effect. *Journal of the Experimental Analysis of Behavior*, 1970, 13, 243-266.
- Honig, W. K. Attention and the modulation of stimulus control. In D. Mostofsky (Ed.), *Attention: contemporary theory and analysis*. New York: Appleton-Century-Crofts, 1970. Pp. 193-238.
- Jenkins, H. and Harrison, R. Effect of discrimination training on auditory generalization. *Journal of Experimental Psychology*, 1960, 59, 246-253.
- Kamin, L. J. "Attention-like" processes in classical conditioning. In M. Jones (Ed.), *Miami symposium on the prediction of behavior: aversive stimulation*. Miami: University of Miami Press, 1968. Pp. 9-31.
- Kamin, L. J. Predictability, surprise, attention, and conditioning. In R. Church and B. Campbell (Eds.), *Punishment and aversive behavior*. New York: Appleton-Century-Crofts, 1969. Pp. 279-296.
- Lett, B. T. Long delay learning in the T-maze. *Learning and Motivation*, 1975, 6, 80-90.
- Moore, B. R. The role of directed Pavlovian reactions in simple instrumental learning in the pigeon. In R. Hinde and J. S. Hinde (Eds.), *Constraints on learning*. New York: Academic Press, 1973. Pp. 159-188.
- Logan, F. A. *Incentive*. New Haven: Yale University Press, 1960.
- Neuringer, A. J. Delayed reinforcement *versus* rein-

- forcement after a fixed interval. *Journal of the Experimental Analysis of Behavior*, 1969, 12, 375-383.
- Rescorla, R. and Wagner, A. A theory of Pavlovian conditioning: variations in the effectiveness of reinforcement and nonreinforcement. In A. Black and W. Prokasy (Eds.), *Classical conditioning II: current theory and research*. New York: Appleton-Century-Crofts, 1972. Pp. 64-99.
- Reynolds, G. S. Attention in the pigeon. *Journal of the Experimental Analysis of Behavior*, 1961, 4, 203-208.
- Skinner, B. F. "Superstition" in the pigeon. *Journal of Experimental Psychology*, 1948, 38, 168-172.
- Williams, B. A. The failure of stimulus control after presence-absence discrimination of click-rate. *Journal of the Experimental Analysis of Behavior*, 1973, 20, 23-27.

Received 28 December 1974.

(Final Acceptance 14 May 1975.)