BLOCKING THE DEVELOPMENT OF STIMULUS CONTROL WHEN STIMULI INDICATE PERIODS OF NONREINFORCEMENT¹

PETER SERAGANIAN AND WALTER VOM SAAL²

MCMASTER UNIVERSITY

To learn whether prior discrimination training based on one stimulus would block learning about a subsequently added stimulus, rats were first trained to press a bar on a variable-interval schedule of food reinforcement. Occasional stimuli were presented during which no reinforcement was available. Responding became suppressed in the presence of these stimuli. Stimuli could be noise, light, or a compound of noise plus light. A group trained with noise in Phase 1, then trained with the compound in Phase 2, showed less suppression to light in a subsequent test than a group that had the same compound training in Phase 2 but only variable-interval training in Phase 1. This showed that prior training with noise blocked the development of control by light during compound training. Two further groups showed that noise training following compound training did not have the same effect on control by light.

Kamin (1968) reported a series of experiments on the conditioned emotional response to shock (CER). Those experiments showed that conditioning to one member of a compound stimulus can be blocked by the presence of a second member to which the response was previously conditioned. In Kamin's study, one group of rats was presented compound stimuli (noise plus light) followed by shock. When tested after training, this group showed considerable suppression to light alone. A second group, which had received prior training with noise alone as the stimulus, showed far less suppression to light after compound training. Prior training with a single stimulus reduced the control developed by the stimulus that was added during compound training. Following Kamin (1968), we refer to this effect as blocking the development of stimulus control.

In the present experiment, blocking was examined in a situation parallel in several respects to that used by Kamin. In this experiment, as in Kamin's, a baseline was obtained by reinforcing the bar press with food on a variable-interval (VI) schedule. Noise and light stimuli were occasionally presented, and

the degree to which these stimuli suppressed responding was evaluated by comparing response rate during the stimulus-on period to the immediately preceding baseline rate. Unlike Kamin's experiments, however, no shock was used, and stimulus periods were simply periods during which no reinforcement was available. The procedure was similar to that typically used in operant-discrimination work, except that nonreinforced periods were relatively brief, and were indicated by the presence of a stimulus that was otherwise absent.

Four groups of rats were used. The first two groups allowed evaluation of the effect of prior training with noise alone on the development of control by light during compound training. This is the basic blocking comparison. For the remaining two groups, the order of training was reversed. The concept of blocking implies that order of training—single stimulus before compound—is important. This proved to be so in Kamin's (1968) study. On the other hand, Johnson and Cumming (1968) suggested that only the amount of training on single and compound stimuli, not order of training, is important in determining the control developed by each stimulus in operant conditioning. The latter two groups allowed examination of this possibility.

METHOD

Subjects and Apparatus

Thirty-two experimentally naive male hooded rats, weighing from 250 to 350 g, were

¹We thank L. J. Kamin, H. M. Jenkins, and S. Scobie for advice and encouragement throughout the course of this research. The research was supported in part by grant APT-103 from the National Research Council of Canada to H. M. Jenkins. Reprints may be obtained from Peter Seraganian, Department of Psychology, Dalhousie University, Halifax, Nova Scotia.

²Now at Princeton University.

obtained from Quebec Breeding Farms. Due to deaths and equipment failures, the data from three subjects were lost. The subjects were put on a 24-hr feeding rhythm which reduced them to approximately 75% of their free-feeding weight. They were maintained at this weight throughout the experiment, being fed once daily approximately 1 hr after each experimental session. The apparatus consisted of standard Grason-Stadler operant conditioning units, with relay, timer, and counter systems providing for automatic scheduling and recording.

The stimulus present during nonreinforced periods was either an 80-db white noise (N), the illumination of an overhead 7.5-w bulb diffused through a milky plastic ceiling (L), or a compound of noise plus light presented simultaneously (NL). The normal condition of the chamber was complete darkness. The ambient noise level for the eight conditioning chambers ranged from 56 to 60 db.

Preliminary training. All subjects were initially trained to press a bar for food (45-mg Noyes food pellets). They were then given five 85-min daily bar-pressing sessions on a 1-min variable-interval (VI 1-min) reinforcement schedule. Intervals used on the VI schedule ranged from 2 sec to 210 sec. Pretests with N and L were given during the last two days of preliminary training. On each of these days, four pretest periods occurred independently of subjects' behavior and without interrupting the VI schedule, in the order L, N, L, N on the first pretest day and N, L, N, L on the second.

Discrimination learning. The subjects were required to discriminate periods of nonreinforcement from the more common condition of VI reinforcement. The N, L, and NL stimuli were used to mark periods during which reinforcement was not available. When a stimulus period occurred, no reinforcements could be obtained for the duration of the stimulus period or for 10 sec after it ended.

The subjects were randomly assigned to four groups of eight subjects each. Each group received different sequences of stimulus periods as indicated in Table 1. A dash in that table indicates that a subject received no stimulus periods and was left on the VI schedule of reinforcement throughout the phase. In both Phase 1 and Phase 2, stimulus periods were 15-min long and occurred twice daily for the

first three days of the phase, but were 3-min long and occurred four times daily for the remaining four days. The use of longer stimulus periods at the beginning of each phase was suggested by pilot work that indicated longer nonreinforced periods would facilitate discrimination learning.

Table 1
Experimental Design and Test Results

Group	Discrimination Learning ^a		Test (1 day)	Suppression Ratio ^b
	Phase 1 (7 days)	Phase 2 (7 days)		
(N-NL)	N	NL	L	0.19
(O-NL)	—	NL	L	0.08
(NL-N)	NL	N	L	0.16
(NL-O)	NL	—	L	0.32

^aStimuli present during nonreinforced periods were noise (N), light (L), or both noise and light (NL). A dash indicates that no nonreinforced periods occurred.

^bSuppression to light on the first stimulus period of the test. A lower ratio indicates more suppression.

Test for control by light. After Phase 2, a test for the effectiveness of L was made. A single test day was given, during which L was presented four times for 3 min each. Once again, no reinforcements were available during the stimulus periods.

Measure. The effect of the stimuli on responding was measured by computing the suppression ratio described by Annau and Kamin (1961). The ratio is $B/(A + B)$, with B representing the number of bar presses during the 3-min stimulus period and A the number of bar presses during the immediately preceding 3 min. A ratio of 0.50 indicates no suppression of responding during the stimulus period; a ratio of 0 indicates complete suppression. With this index, therefore, a lower value indicates stronger stimulus control over responding. When a 15-min stimulus period was employed, the ratio was based on the first 3 min of the period to allow comparison with 3-min stimulus periods. When no stimulus period was used, responses were recorded as if a stimulus period had occurred, and suppression ratios were calculated on the basis of these dummy periods. Dummy periods were used for recording purposes only: no stimulus was presented during these periods, and reinforcement remained available on the VI schedule.

RESULTS

Baseline rates of responding rose gradually during the course of the experiment. Median rate for all subjects during those portions of the session with no stimulus present rose from 21 responses per min on the last day of preliminary training to 37 responses per min on the last day of Phase 2 and on the test. Throughout both phases of training and the test, there was considerable overlap between groups in both baseline rate of responding and rate during stimulus periods. The treatments examined had their consistent effects in terms of a change in rate, for each subject, from baseline to stimulus period. For this reason the results reported below are in terms of a score based on this change.

Pretests. The pretests showed that the presentation of light alone reduced rate of responding slightly, while noise had no effect. Median suppression ratios to L and to N were 0.38 and 0.50 for the first presentation of these stimuli and were 0.43 and 0.53 for the last presentation. There were no differences between groups during pretest.

Discrimination learning. Median suppression ratios for each group are shown in Fig. 1. Data for individual subjects are shown in Table 2. Groups (N-NL), (NL-N), and (NL-O) each learned to suppress responding during

stimulus periods in Phase 1. Groups (NL-N) and (NL-O), which had compound stimulus periods, learned to suppress responding more rapidly than Group (N-NL), which had stimulus periods of noise alone. Suppression ratios for the fourth stimulus period were significantly lower in subjects trained with the compound than in subjects trained with noise alone. There was almost no overlap between subjects in Groups (NL-N) and (NL-O) and subjects in Group (N-NL) in this measure (Mann-Whitney $U = 2$, two-tailed $p < 0.002$). By the end of Phase 1, however, there were no significant differences among the three groups receiving stimulus periods in that Phase (see Table 2). Suppression ratios in Group (O-NL), calculated on the basis of dummy periods, remained near 0.50 throughout Phase 1.

Subjects in Group (N-NL) had an additional stimulus added to their stimulus period in Phase 2, while subjects in Group (NL-N) had a stimulus removed. The addition of light in Group (N-NL) had no strong effect: four subjects showed less suppression in the first period of Phase 2 than in the last period of Phase 1, and three subjects showed more (Table 2). However, the removal of light from the stimulus period in Group (NL-N) did have a large effect: the median suppression ratio for the last period of Phase 1 was 0.10, while the median ratio for the first period of Phase 2

Fig. 1. Median suppression ratios for each group during training and test. A ratio of 0.50 indicates no suppression: lower ratios indicate more suppression. The first six stimulus periods of Phases 1 and 2 were 15 min long and occurred twice daily. The remaining stimulus periods were 3 min long and occurred four times daily. Only the first 3 min of a 15-min stimulus period were used in computing suppression ratios.

Table 2
Suppression Ratios for Individual Subjects

Phase 1 Periods						Phase 2 Periods						Test Periods			
1	2	3	20	21	22	23	24	25	42	43	44	1	2	3	4
GROUP (N-NL)															
0.53	0.44	0.51	0.27	0.28	0.40	0.13	0.10	0.04	0.07	0.06	0.05	0.15	0.11	0.11	0.10
0.45	0.44	0.37	0.01	0.08	0.04	0.23	0.09	0.07	0.01	0.02	0.01	0.18	0.07	0.14	0.12
0.53	0.52	0.54	0.26	0.35	0.28	0.24	0.07	0.10	0.06	0.26	0.06	0.19	0.11	0.14	0.08
0.52	0.44	0.43	0.21	0.09	0.13	0.34	0.03	0.25	0.40	0.32	0.26	0.37	0.31	0.28	0.21
0.45	0.51	0.40	0.11	0.10	0.12	0.06	0.04	0.01	0.17	0.28	0.14	0.24	0.11	0.18	0.18
0.47	0.55	0.39	0.03	0.07	0.02	0.10	0.04	0.03	0.06	0.07	0.01	0.16	0.13	0.09	0.09
0.55	0.49	0.51	0.40	0.23	0.19	0.30	0.14	0.14	0.03	0.00	0.00	0.38	0.30	0.16	0.37
0.52	0.49	0.43	0.21	0.10	0.13	0.23	0.07	0.07	0.06	0.07	0.05	0.19	0.11	0.14	0.12
GROUP (O-NL)															
0.55	0.44	0.48	0.57	0.45	0.52	0.39	0.27	0.11	0.01	0.03	0.01	0.16	0.18	0.14	0.15
0.53	0.51	0.54	0.47	0.49	0.57	0.38	0.23	0.04	0.00	0.09	0.06	0.11	0.04	0.06	0.08
0.51	0.44	0.49	0.52	0.53	0.62	0.41	0.25	0.24	0.02	0.00	0.03	0.13	0.20	0.06	0.07
0.43	0.46	0.50	0.37	0.68	0.50	0.45	0.37	0.13	0.03	0.06	0.01	0.08	0.05	0.04	0.03
0.51	0.46	0.53	0.38	0.28	0.49	0.39	0.31	0.18	0.03	0.08	0.10	0.07	0.02	0.06	0.04
0.46	0.44	0.50	0.54	0.46	0.55	0.58	0.27	0.16	0.04	0.01	0.04	0.04	0.02	0.06	0.01
0.49	0.42	0.57	0.47	0.48	0.51	0.27	0.14	0.16	0.00	0.02	0.00	0.02	0.02	0.06	0.14
0.51	0.44	0.50	0.47	0.48	0.52	0.39	0.27	0.16	0.02	0.03	0.03	0.08	0.04	0.06	0.07
GROUP (NL-N)															
0.52	0.47	0.29	0.05	0.00	0.04	0.45	0.47	0.46	0.10	0.29	0.11	0.31	0.17	0.13	0.21
0.49	0.37	0.45	0.11	0.11	0.16	0.57	0.42	0.28	0.05	0.36	0.15	0.15	0.12	0.05	0.04
0.40	0.43	0.24	0.14	0.09	0.07	0.43	0.46	0.42	0.25	0.11	0.17	0.09	0.03	0.08	0.02
0.35	0.19	0.20	0.12	0.17	0.19	0.46	0.39	0.52	0.12	0.19	0.07	0.16	0.10	0.19	0.17
0.24	0.22	0.22	0.03	0.04	0.00	0.49	0.43	0.36	0.22	0.21	0.12	0.23	0.12	0.11	0.10
0.49	0.44	0.34	0.11	0.07	0.12	0.42	0.42	0.21	0.08	0.31	0.01	0.16	0.46	0.17	0.04
0.48	0.43	0.34	0.01	0.00	0.00	0.32	0.30	0.19	0.07	0.13	0.11	0.13	0.08	0.00	0.09
*	0.38	0.41	0.22	0.23	0.19	0.50	0.47	0.45	0.20	0.36	0.25	0.18	0.07	0.12	0.09
0.48	0.41	0.32	0.11	0.08	0.10	0.46	0.42	0.39	0.11	0.25	0.12	0.16	0.11	0.12	0.09
GROUP (NL-O)															
0.45	0.40	0.33	0.09	0.07	0.03	0.52	0.54	0.50	0.49	0.42	0.46	0.37	0.27	0.18	0.32
*	0.35	0.29	0.06	0.00	0.02	0.54	0.43	0.59	0.51	0.47	0.52	0.32	0.33	0.22	0.25
0.35	0.44	0.39	0.11	0.16	0.11	0.53	0.50	0.50	0.48	0.49	0.58	0.42	0.17	0.32	0.32
0.34	0.30	0.14	0.09	0.09	0.14	0.44	0.49	0.62	0.48	0.46	0.50	0.35	0.51	0.21	0.27
0.54	0.42	0.35	0.26	0.07	0.23	0.46	0.68	0.52	0.58	0.35	0.47	0.25	0.22	0.18	0.15
0.55	0.44	0.44	0.00	0.02	0.00	0.59	0.49	0.53	0.49	0.52	0.42	0.28	0.20	0.17	0.21
0.14	0.14	0.25	0.01	0.00	0.00	0.58	0.45	0.65	0.44	0.58	0.61	0.04	0.09	0.05	0.03
0.40	0.40	0.33	0.09	0.07	0.03	0.53	0.49	0.53	0.49	0.47	0.50	0.32	0.22	0.18	0.25

NOTE—Italicized entries are group medians.
* Data lost due to apparatus recording error.

increased to 0.46, showing considerable loss of stimulus control. All eight subjects in Group (NL-N) showed a difference in this direction ($p < 0.01$ by a sign test).
In Phase 2, Groups (N-NL) and (O-NL) learned to suppress responding to the compound stimulus. Suppression ratios for the first stimulus period of Phase 2 were significantly lower in Group (N-NL) than in Group (O-NL), showing a beneficial effect of prior training with N ($U = 2, p < 0.002$). However, this difference was no longer significant by

the third stimulus period of Phase 2, and the performances of the two groups were similar throughout the remainder of Phase 2. The course of learning in Group (O-NL) in Phase 2 was also similar to that of Groups (NL-N) and (NL-O) in Phase 1, showing that the extra seven days of VI training given Group (O-NL) had no strong effect on learning.
Comparison of three groups that received stimulus periods during Phase 2 showed greater suppression to the compound than to noise alone. Median suppression ratios in

Groups (N-NL) and (O-NL) were consistently lower than those in Group (NL-N) throughout Phase 2. Suppression ratios for the last stimulus period of Phase 2 were significantly lower in Group (O-NL) than in Group (NL-N) ($U = 6$, $p < 0.02$), but the difference between Groups (N-NL) and (NL-N) was not significant (Table 2). Suppression ratios for Group (NL-O), calculated on the basis of dummy periods, remained near 0.50 throughout Phase 2.

Test for control by light. On the test day, four nonreinforced L periods were presented. Median suppression ratios for each period are shown in Fig. 1, and individual data are given in Table 2. The data described below are suppression ratios for the first L period only. The differences between groups observed in the first period were apparent in all four test periods, although levels of significance dropped slightly as all groups learned to suppress responding to L.

Median suppression ratios for the first test period are shown in Table 1. A Kruskal-Wallis one-way analysis of variance showed a significant effect of group on first test period suppression ratio ($p < 0.01$). Comparisons between individual groups were made using the Mann-Whitney U test (two-tailed comparisons). The critical comparison for demonstrating blocking is between Groups (N-NL) (O-NL). The suppression ratios in Group (N-NL) were significantly higher than those in Group (O-NL), indicating less suppression to L in Group (N-NL) ($U = 1.5$, $p < 0.002$). The ratios in Group (NL-N) were significantly lower than those in Group (NL-O) ($U = 10$, $p < 0.05$). Finally, ratios in Group (O-NL) were significantly lower than those in either Group (NL-N) ($U = 6.5$, $p < 0.02$) or Group (NL-O) ($U = 6.5$, $p < 0.03$). The remaining two comparisons did not approach significance.

DISCUSSION

The fact that there was less suppression to light in Group (N-NL) than in Group (O-NL) on the test showed that blocking occurred. Although these groups had identical experience with the compound stimulus, the group with prior training on noise showed less suppression to light than the group without such prior training. Prior training to suppress responding to noise diminished the control developed over responding by light. This finding

parallels the finding of Kamin (1968) and demonstrates that blocking can occur in a situation where the stimuli, instead of predicting shock, are present during periods of nonreinforcement. The magnitude of the blocking effect found by Kamin (1968) was considerably greater than that found here. First test period suppression ratios to light in Groups (N-NL) and (O-NL) were 0.19 and 0.08; first test period ratios from comparable groups reported by Kamin (1968) were 0.45 and 0.05. Despite the reduced magnitude of the difference between groups in this experiment, the blocking effect remained highly significant, since there was so little overlap between groups.

Johnson and Cumming (1968, Exp. II) ran groups of pigeons under conditions analogous to those of the present Groups (N-NL) and (NL-N) and found, as we did, that control by the equivalent of the present light stimulus was similar in these two groups. Although their comparison involved a total of only three subjects, Johnson (1966) observed the same result with a larger number of subjects. These authors suggested that the amount of training on single and compound stimuli is important in determining the control shown by a stimulus, but the order of that training is not important. The results for the present additional groups lead us to question this conclusion.

First, a distinction must be made between the development of control during a particular phase of training and the extent to which this control is revealed on a later test. Although Groups (N-NL) and (NL-N) showed almost identical suppression to light on the test (Table 1), one cannot conclude that learning about light within the noise-light phase was the same in these two groups. Note that Group (N-NL) was tested immediately after compound training, whereas seven days of further training intervened between compound training and test in Group (NL-N). This intervening training may have reduced control of light on the test: recall that Group (NL-O) had considerably less control by light than Group (O-NL). Because the relation between compound training and test was quite different in Groups (N-NL) and (NL-N), the observation of equivalent control by light in these two groups on the test cannot justify a conclusion of equivalent learning about light during the compound phase.

Second, one may ask whether the control shown by light on the test was affected by noise training in the same way whether noise training preceded or followed compound training. A direct comparison of Groups (N-NL) and (NL-N) will not answer this question, since these groups differed in two ways: order of training on noise and noise-light, and amount of training intervening between noise-light training and test. To isolate the effect of noise training in these groups, each group must be compared to an appropriate control group that received compound training in the same location with respect to the test, but no noise training. Specifically, the difference between Groups (N-NL) and (O-NL) must be compared with the difference between Groups (NL-N) and (NL-O). The results showed that Group (N-NL) had less suppression to light than Group (O-NL), but Group (NL-N) did not have less suppression to light than Group (NL-O). This interaction between location of compound training and effect of noise periods *versus* no stimulus periods was found to be highly significant by a two-way analysis of variance on the first test period suppression ratios ($F = 16.3$, $df = 1,25$, $p < 0.001$). Some part of this interaction is due to the fact that suppression to light was greater in Group

(NL-N) than in Group (NL-O). It is not clear why continued training on noise caused greater suppression to light in Group (NL-N); this effect may have been due to generalization from noise to light, or to continued experience with nonreinforced periods of 3-min duration in Phase 2. It is clear, however, that a reduction in control by light attributable specifically to training with noise alone occurred only when that noise training preceded compound training.

REFERENCES

- Annau, Z. and Kamin, L. J. The conditioned emotional response as a function of intensity of the US. *Journal of Comparative and Physiological Psychology*, 1961, 54, 428-432.
- Johnson, D. F. *Determiners of selective discriminative stimulus control*. Unpublished doctoral dissertation, Columbia University, 1966.
- Johnson, D. F. and Cumming, W. H. Some determiners of attention. *Journal of the Experimental Analysis of Behavior*, 1968, 11, 157-166.
- Kamin, L. J. "Attention-like" processes in classical conditioning. In M. R. Jones (Ed.), *Miami symposium on the prediction of behavior, 1967: aversive stimulation*. Coral Gables, Fla.: University of Miami Press, 1968. Pp. 9-31.

Received 17 February 1969.