AN AVERSIVE STIMULUS AS A CORRELATED BLOCK COUNTER IN FR PERFORMANCE¹

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After the performances of two pigeons had stabilized on an FR 100 grain reinforcement schedule, response-contingent shock was introduced in the form of a block counter. When shock intensity increased in successive thirds of the ratio, duration of post-reinforcement pauses increased and local rate in an advanced part of the ratio declined. With decrements of shock intensity in successive thirds of the ratio, running rate was not consistently affected but pauses after reinforcements were longer than those under the increasing counter. The results are interpreted in terms of the interaction among some controlling variables operating in the behavioral chain.

Ferster and Skinner (1957) have described the effects of an added counter on FR performance. One type of counter used in their investigations changed in discrete steps after specified fractions of the ratio were completed. This block counter was found to exert considerable control over behavior. Performance under the block counter was considered to be a case of chained behavior since emission of responses produced changes of the counter values during the ratio. Chained schedules and the concept of chaining have been treated recently by Kelleher and Gollub (1962).

If each response in an FR schedule is punished, but successive blocks of responses are punished with differential severity, the punishing stimulus would function as a block counter. Each intensity of punishment would define a member in the response chain. In this context, the punishing stimulus would acquire discriminative and positively reinforcing properties in addition to its noxious property. Holz and Azrin (1962) have described the interaction of discriminative and aversive effects of punishment on FI behavior.

The present study concerns the effects on a

food-reinforced operant of response-contingent shock programmed as a block counter. In one case, the shock intensity increased after completion of a specified number of responses; in the second case, completion of a block of responses produced a decrement of shock intensity.

METHOD

Subjects

Two male White Carneaux pigeons (Palmetto), about 2 yr old at the start of the study, were used. Histories included FR schedules not exceeding 100 for both subjects (Ss) and response-contingent shock as a block counter for B-59. Pre-session body weights of both Ss averaged 77% of free-feeding weight. For B-59, the average pre-session electrical resistance was 1,134 ohms and average post-session resistance, 1,149 ohms; for B-79, average pre-session resistance was 808 ohms and average post-session resistance 817 ohms. For those sessions in which shock was administered, minimum and maximum resistances were 520 ohms and 1,580 ohms for B-59 and 640 ohms and 1,080 ohms for B-79. Between experimental sessions, Ss were housed in separate units with continuous access to community water and grit troughs.

Apparatus

The 14 by 14 by 14.5 in. experimental chamber was set within a refrigerator compartment and provided with ventilation and

¹This investigation was conducted at Anna State Hospital and was supported by a grant from the Psychiatric Training and Research Fund of the Illinois Department of Public Welfare. The assistance of the personnel of the Behavior Research Laboratory, especially M. Kelley and R. Bittle, throughout the study is acknowledged.

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masking noise. A translucent key, operated by a force of approximately 15 g, was located 9.5 in. above the mesh floor and 1 in. to the right of the front panel midline. Each response on the key produced a click by activating a relay mounted on the exterior of the front panel. The opening to the food magazine was centered at the bottom of the front panel. The magazine contained mixed grain, individual seeds of which did not pass $\frac{1}{8}$ in. holes. Duration of grain exposure was 3 sec. The house light and key light were on continuously except during reinforcement. Running speed of the Gerbrands cumulative recorder was 60 cm/hr.

A regulated electric current was connected by a relay to a circuit consisting of the *S*, a milliammeter, and a 10 K resistor. The shock was applied to the *S* through fixed electrodes (Azrin, 1959a). Shock duration was .05 sec. One intensity of shock was present during the first 33 responses, a second intensity during the second 33 responses, and a third intensity during the final 34 responses of the ratio. In the report, shock intensity is specified in terms of current passing through the *S* assuming a constant fixed resistance of 1 K for the *S*. The series of shock intensities delivered during a ratio was one of the following: (1) .6, 1.4, 2.2 ma; (2) 1.0, 2.2, 3.4 ma; (3) 1.4, 3.0, 4.6 ma. The maximum variation from these values, based on the maximum changes in the *S*'s resistance, was estimated as $\pm 10\%$ of each value. Each of these shock series was presented in increasing and decreasing order of magnitude which provided six shock conditions. Each condition is denoted by the letter I or D to indicate increasing or decreasing intensities respectively, and by the number 1, 2, or 3 which identifies the low, intermediate, or high intensity series.

Procedure

Sessions were scheduled daily, seven days a week. Duration of each session was 1 hr or delivery of all programmed reinforcements. Maximum frequency of reinforcements was 40 for B-59 and 50 for B-79. The electrical resistance of each *S* was measured before and after each session. If the resistance exceeded 2 K, it was reduced by cleaning the electrodes.

After the FR 100 performance had stabilized, the first shock condition was administered. Each of the six shock conditions was con-

tinued until the behavior appeared stable. The qualitative criterion was five consecutive sessions without any discernible trend. Several sessions without shock were scheduled after each shock condition to avoid cumulative effects, observe the permanence of the behavioral modifications associated with a shock condition, and provide data on the initial reaction to each shock condition. Each shock contingency was added and removed during the course of a session. A summary of the procedure is shown in Table 1. The sessions without shock which followed each shock condition are not listed in the table.

Table 1

Order of administration of the Six Shock Conditions and the Frequency of Sessions and Reinforcements under each Condition. Current values for each Sequence in ma.

B-59			B-79		
Sequence	Sessions	S ^a	Sequence	Sessions	S ^a
I-1 (.6, 1.4, 2.2)	8	320	I-1	15	750
I-2 (1.0, 2.2, 3.4)	12	480	I-2	11	550
D-1 (2.2, 1.4, .6)	11	440	I-3	11	550
D-2 (3.4, 2.2, 1.0)	10	400	D-1	12	600
D-3 (4.6, 3.0, 1.4)	19	479	D-2	7	350
I-3 (1.4, 3.0, 4.6)	22	392	D-3	14	540
			I-3	7	350
			I-1	9	450

RESULTS

The use of changes in shock intensity as a block counter is limited by absence of information on the absolute and difference thresholds of each *S* for shock. A further complication is possible non-noxious properties of low intensity shock. For these reasons, performances under all shock conditions are presented. The initial experience of each *S* with shock provided an approximation of absolute sensitivity because the shock would function as a novel stimulus. The first exposure of B-59 to shock resulted in a disruption of FR performance under 1.1 ma and no reaction to .4 ma; the first exposure of B-79 revealed a disruption under 1.4 ma and no reaction to .6 ma. These values for B-59 are based on preliminary studies. It should be noted that lack of a reaction to the introduction of a low intensity stimulus does not necessarily prevent that stimulus from developing into an S^D.

Cumulative records of final performances under each of the six shock conditions are

shown in Fig. 1 for B-59 and in Fig. 2 for B-79. Each of the cumulative records represents an entire session unless otherwise noted. The top record in each figure illustrates the FR performance prior to the administration of the first shock contingency. B-59 appeared to be more sensitive to the shock condition; so, the performances of the two Ss under a given condition are not comparable.

Details of the running rate under each condition for each S are shown in Fig. 3. Each group of ratios was selected to show the major variations which occurred under each shock contingency.

Increasing Block Counter. The distinctive property of the performances under the increasing block counter was the local reduction in response rate during an advanced member of the FR 33 FR 33 FR 34 chain. This effect appeared under the I-3 shock sequence for B-79 and under all increasing shock sequences for B-59. In the case of B-59, the reduction in rate was localized largely in the final third of the ratio under the I-1 sequence and in the

middle third under the I-2 sequence. The reduction was intensified under the I-2 sequence. Occasionally, under the I-2 sequence, a tri-valued rate was present resulting from a further reduction of running rate in the final third of the ratio.

Under the I-3 sequence, the behavior of B-59 was severely strained. In contrast to the rapid transition to a stable behavior which occurred under the I-1 and I-2 sequences, a recurrent behavior pattern did not appear until the 17th session. The trend of the performances consisted of an increased suppression to the eighth session, a low response frequency for several sessions, then a gradual recovery to the 17th session. The full quota of reinforcements was obtained in the 2nd, 18th, and 20th sessions; the minimum response frequency of 55 occurred in the 12th session. The abrupt intra-session recovery seen in record I-3 of Fig. 1 was characteristic of the later sessions under this condition. This record demonstrates an interesting property of the performances under the increasing counter, namely, the extreme resistance of responding to breaks during the last third of the ratio despite the reduction in running rate.

The local reduction in running rate during an advanced part of the ratio occurred only under the I-3 sequence for B-79 and was less stable and less marked than that shown by B-59. The shift to the lower rate was usually concurrent with onset of the second shock intensity, but, quite frequently, the reduction did not appear until the final third of the ratio. A uniformly lower rate or, as in the case of B-59, a tri-valued rate occurred occasionally. Although the running rate of B-79 was affected by the I-2 sequence, the modification consisted of a uniformly reduced rate throughout the ratio, or a lower rate during the first third of the ratio. This result might reflect the shorter history of B-79 with the block counter and/or the less highly developed FR performance. The performance of B-79 was unaffected by the I-1 shock sequence.

Other modifications in the FR performances of both Ss under the increasing counter were frequent occurrences of rough grain and short breaks prior to the initiation of the running rate and also an increase in the duration of post-reinforcement pauses. With the exception of the performances of B-59 under the I-3 sequence, the duration of the extended pauses

Fig. 1. Cumulative records of B-59 illustrating the baseline performance and the final FR performances observed under each of the six shock conditions. Each record is a complete session. Pips indicate the onset of the next shock intensity in the sequence. Labels before each record designate the shock condition in effect. Sessions shown are I-1, 8; I-2, 11; I-3, 22; D-1, 11; D-2, 8; D-3, 15.

Fig. 2. Cumulative records of B-79 showing the baseline FR performance and the final performances under each of the six shock conditions. Each record is a complete session. Pips indicate the onset of the next shock intensity. Labels designate the shock condition. Sessions shown are I-1, 9; I-2, 11; I-3, 10; D-1, 12; D-2, 7; D-3, 11.

did not exceed the maximum duration of post-reinforcement pauses in the pre-shock performance.

Decreasing Block Counter. Under the decreasing counter, the performances of both Ss exhibited response breaks at the start of the ratio and an increase in the duration of post-reinforcement pauses. These effects appeared under the D-1 sequence and were intensified under the D-2 and D-3 sequences for both Ss. For a given set of shock values, post-reinforcement pausing was longer under the decreasing counter than under the increasing counter. A consistent local reduction in running rate was not observed under the decreasing counter. Note that the running rate of B-79 under the D-3 sequence was more uniform and often higher than under other shock sequences and under no-shock.

The behavior of B-59 under the D-3 condition showed increasing strain on successive

sessions and, unlike the strained performance under the I-3 condition, did not exhibit any recovery. In the final four sessions, a total of four reinforcements was obtained. The session shown in Fig. 1 was the last session in which appreciable responding occurred.

The differential effect of the increasing and decreasing block counters can be seen by contrasting the performances of B-79 under the I-3 and D-3 conditions and also the performances of B-59 under each type of counter for a given set of shock intensities. The differing effect of the counters illustrates that the absolute value of shock intensity was subordinate to the location of that intensity in the sequence and to the order of intensities in the sequence. For example, in the case of B-59, the onset of 2.2 ma in the second segment of the ratio in the I-2 sequence was associated with an immediate reduction of running rate whereas this same intensity located in the

Fig. 3. Typical ratios of B-59 and of B-79 under each of the six shock conditions. Pips indicate onset of the next shock intensity; labels denote the shock condition.

same part of the ratio in the D-2 sequence did not affect running rate. Also, the 3.4 ma intensity in the final segment of the ratio with the I-2 sequence was associated with a uniformly lower running rate, but the same intensity, which occurred in the first third of the ratio with the decreasing counter, resulted in rough grain and response breaks.

Summary of Overall Rates. The overall response rate in each of the final five sessions under each shock condition and each non-shock condition are shown in Fig. 4 for B-59 and Fig. 5 for B-79. The conditions are listed in the order in which they were administered. Open circles indicate absence of shock; solid circles, presence of shock. Note the increased variability of overall rate shown by B-59 after removal of the I-3 and D-3 shock contingencies which had disrupted the behavior severely. In contrast, the overall rates of B-79 after removal of these shock contingencies were higher than other no-shock overall rates.

With a given set of shock intensities, overall rates were lower when these intensities comprised a decreasing block counter. An exception was the higher rate of B-59 under the D-1 sequence relative to that under the I-1 sequence. However, during preliminary sessions

Fig. 4. Overall rate in each of the last five sessions of each experimental condition for B-59. Conditions are shown in the order of administration. Open circles denote absence of shock; solid circles denote presence of shock. Labels on the abscissa indicate the shock condition in effect.

with B-59, administration of the D-1 sequence immediately after the I-1 sequence resulted in a lower rate under the D-1 condition. Therefore, the exception might reflect an unreliable effect of low shock intensities or a sequential effect.

Addition and Removal of the Shock Conditions. When the increasing block counter was added during the course of a session, many of the characteristics of the final behavior under that condition appeared immediately. Removal of the shock condition always resulted in an immediate recovery of the FR performance. In most cases, after the removal of the shock contingency, several ratios were

Fig. 5. Overall rate in each of the last five sessions for each condition for B-79. Open circles denote the absence of shock; solid circles, presence of shock. Labels on the abscissa indicate the shock condition in effect. Conditions are shown in the order of administration.

completed without a post-reinforcement pause. This absence of post-reinforcement pausing was most marked after removal of the I-3 and D-3 shock sequences. Those sessions in which each shock condition was added and removed for B-59 are shown in Fig. 6. The arrows indicate the point at which the change was instituted. The horizontal arrow in record D-3 indicates that the shock was removed prior to that part of the session which is included in the figure. B-59 had not emitted any responses prior to the part of the session which is shown in Fig. 6.

B-79 exhibited similar effects when the contingencies were added and removed. The only unique reaction by B-79 was a brief but marked disruption when the I-1 sequence was introduced; however, that occasion represented the initial experience of B-79 with shock.

DISCUSSION

The differential effect of the increasing and decreasing block counters can be interpreted in terms of the interaction of some of the controlling variables. These variables include absolute intensity of shock, count in the ratio, and reinforcing capacity of the change in shock intensity. With the decreasing counter, probability of response after reinforcement would be lower than at any other point of the ratio, due to the additive effects of maximum intensity of response-contingent shock and zero count in the ratio. With the increasing counter, probability of response following reinforcement would be higher than in the former situation since the minimum shock intensity was scheduled. An additional factor would be the differential reinforcing capacity of the change of shock intensity defining the

Fig. 6. Cumulative records of B-59 for those sessions in which each shock contingency was added or removed. Labels denote the shock condition and refer to records to the right and left of the label. Pips indicate a change of shock intensity. Arrows indicate the point at which the shock contingency was added or removed. All records are complete sessions except for the record labelled "D-3, Shock removed."

second member of the chain. In the decreasing counter, onset of the second intensity acquired reinforcing properties from its association with the accumulated count and its reduced intensity; in the increasing counter, the reinforcing effect of the advanced count was counteracted by the increased intensity of shock.

Accordingly, the reinforcing property of the second shock intensity should be greater in the decreasing counter. Since post-reinforcement pausing was no longer under the decreasing counter, it can be assumed that the aversive stimuli present after reinforcement under the decreasing counter sufficiently offset the greater reinforcing capacity of the shock intensity change to produce a response probability lower than that under the increasing counter. However, once responding was initiated under the decreasing counter, the increased proximity to the shock intensity decrement would increase its reinforcing effect and the response probability would increase rapidly.

Responding in the second and third members of the chain under each type of counter can be interpreted in the same manner. In general, continued emission of responses under the decreasing counter produced increasingly favorable occasions for responding. Therefore, once responding was initiated, further responding was more probable. With the increasing block counter, initial responding was more probable than under the decreasing counter, but continued responding produced

an increasingly intense conflict situation. The strengths of the reinforcing and aversive events increased. The reduced rate during the final third of the ratio under the increasing counter illustrates the unified nature of chained behavior. This last segment cannot be considered as an FR 34 with all responses punished since it has been shown that constant intensity response-contingent shock in a short FR does not affect running rate (Azrin, 1959b).

Concerning the relative effectiveness of each type of counter for suppressing FR performance, the behavior shown under the conditions employed in this study suggests that the decreasing block counter is more effective. The basis would appear to be the application of maximum punishment to that part of the ratio in which probability of response is minimal.

REFERENCES

- Azrin, N. H. A technique for delivering shock to pigeons. *J. exp. Anal. Behav.*, 1959(a), 2, 161-163.
- Azrin, N. H. Punishment and recovery during fixed-ratio performance. *J. exp. Anal. Behav.*, 1959(b), 2, 301-305.
- Ferster, C. B. and Skinner, B. F. *Schedules of reinforcement*. New York: Appleton-Century-Crofts, 1957.
- Holz, W. C. and Azrin, N. H. Interactions between the discriminative and aversive properties of punishment. *J. exp. Anal. Behav.*, 1962, 5, 229-234.
- Kelleher, R. T. and Gollub, L. R. A review of positive conditioned reinforcement. *J. exp. Anal. Behav.*, 1962, 5, 543-597.

Received March 20, 1963