EFFECTS OF TIMEOUT ON SPACED RESPONDING IN PIGEONS

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Three pigeons were trained under a differential-reinforcement-of-low-rate schedule of 20 sec, and then exposed to a schedule under which responses terminating interresponse times less than 20 sec produced timeout and responses terminating interresponse times greater than 20 sec produced reinforcement. Response-produced timeouts selectively decreased the probability of short interresponse times and thereby produced a higher frequency of reinforcement. The suppressive effect of timeout was independent of timeout duration, with timeouts of 5, 10, or 20 sec. Similar effects were found when the minimum interresponse time that could be terminated by response-produced reinforcement was increased to 30 sec. The suppressive effects of timeout on responding maintained by these schedules were similar to previous reports in which responding was punished with electric shock.

Under a schedule that differentially reinforces low rates of responding (DRL), interresponse times (IRTs) that end after a predetermined time interval are followed by reinforcement (Wilson and Keller, 1953). Reynolds (1964 *a, b*) has shown that pigeons perform at an inefficient rate on a DRL 20-sec schedule while maintained at 80% of free-feeding weight. He reported that the performance after over 100 sessions on the schedule was basically unchanged from that after six sessions. The subjects emitted few responses with long IRTs, and the data presented gave no indication that the subjects had formed a temporal discrimination. Reynolds (1964*b*) concluded that pigeons fail to discriminate among durations of IRTs from 4 to 20 sec.

Staddon (1965) exposed pigeons to DRL schedules of 30, 15, 20, 5, 10, 20, and 30 sec, in that order, until stable performance was reached on each schedule. On the second exposure to DRL 20-sec, the birds responded at a low rate that was close to maximum effi-

ciency, while the pattern of responding indicated that they had formed a temporal discrimination. Staddon's results suggest that this efficient performance was due to repeated exposure to different DRL values causing a shift in performance toward greater efficiency with each succeeding schedule. This in turn suggests that exposure to one DRL value for a long period of time would not be as effective in producing adjustment to the schedule requirements as would exposure to several values of a DRL schedule, a conclusion partially supported by the data of Reynolds (1964*b*). However, these conclusions do not apply to DRL 30-sec. On the second exposure to DRL 30-sec, two of the three birds responded at a higher rate than during the preceding DRL 20-sec schedule, thus indicating a failure to adjust to the schedule at that value. Staddon concluded that few pigeons, when exposed to DRL 30-sec, could adjust their rate of responding to the schedule requirements in a way comparable to their adjustment to shorter intervals.

Holz and Azrin (1963) investigated several procedures for eliminating behavior in pigeons on a DRL 30-sec schedule. Here again stable performance on the schedule was inefficient in that a high percentage of the IRTs were short (0 to 5 sec) with a monotonically decreasing percentage of IRTs falling into successive 5-sec categories. Only about 1% of the IRTs were reinforced. When all responses were punished with shock, the IRT distributions changed in an orderly fashion. As shock in-

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tensity increased, more of the short IRTs were eliminated and the mode of the distribution shifted toward longer IRTs. In a complementary study Holz, Azrin, and Ulrich (1963) essentially replicated these results. They found that punishment of all responses with shock decreased the rate of responding as a direct function of shock intensity, and in particular reduced the number of short IRTs, even at low intensities. But after punishment was removed in both experiments, the IRT distributions returned to pre-punishment values, even if punishment had greatly suppressed responding. Holz and Azrin did point out that complete suppression was achieved with some birds at very high shock intensities after punishment was removed. Thus, punishment with shock does suppress responding on a DRL schedule but has no lasting effect if responding is not eliminated.

Leitenberg (1965), in a review of the literature, concluded that timeout from positive reinforcement is aversive; the behavior which produces it is suppressed. The purpose of the present experiment was to see if response-produced timeout could decrease the frequency of short IRTs on both DRL 20-sec and DRL 30-sec, thereby facilitating performance in a manner similar to that reported with electric shock.

METHOD

Subjects

Three experimentally naive male White Carneaux pigeons were maintained at 80% of their free-feeding weight.

Apparatus

The apparatus consisted of a three-key pigeon chamber. The pigeons responded by pecking the center key with a minimum of 15 g of force. Each response that met the DRL requirement was reinforced with 6-sec access to grain. Further specifications are described elsewhere (Rilling, 1967). The IRTs were printed out on a Lehigh Valley Electronics nine-channel serial-parallel entry printer, model 1660-9.

Procedure

During Session 1, pecks on the center key were conditioned. Each response produced food and the session was terminated after food

had been delivered 25 times. Starting with Session 2, the houselights were on and the center key was illuminated with white light. The subjects were placed on a DRL t -sec schedule, where t represents the IRT from either: (1) the last response, (2) the last reinforcement termination, or (3) the start of the session, whichever had occurred most recently. For Session 2, t was 3 sec and was progressively increased by 1 sec each day until DRL 20-sec was reached. The criterion for terminating a daily session throughout the experiment was either (1) 25 reinforced responses or (2) 2 hr of presentation of the illuminated center key, whichever occurred first. Sessions were conducted on the average of six days out of seven.

The experiment was composed of five conditions. The first was 20 sessions under a DRL 20-sec schedule. The second condition lasted 30 sessions. During alternate sessions, every center-key response with an IRT of less than 20 sec was followed by a timeout of either 5, 10, or 20 sec for the entire session. A timeout consisted of completely darkening the experimental chamber by turning out the house and key lights. Responses with IRTs of 20 sec or longer did not produce a timeout but were followed by reinforcement. The order of occurrence of the different timeout values was variable for each bird, five sessions being run at each of the three timeout values. For those sessions in which timeouts occurred, IRTs were measured from either: (1) the start of the session, (2) the last reinforcement termination, or (3) the last timeout termination, whichever had occurred most recently. Thus, the time spent in darkness was not included as part of the time between responses. For those sessions in which timeouts did not occur, the procedure was, as before, DRL 20-sec.

The third condition was the same as the first, DRL 20-sec with no timeout, and lasted for 15 sessions. For condition four, the delay requirement for reinforcement was increased to 30 sec (DRL 30-sec) for 10 sessions. In the fifth condition, all responses with IRTs of less than 30 sec were followed by a timeout during alternate sessions for the next 30 sessions, using the same timeout values and procedure as in the second DRL 20-sec condition.

RESULTS

Table 1 shows the rates of responding and rates of reinforcement for each bird during

the timeout procedure for both DRL 20-sec and DRL 30-sec. The time spent in darkness was not included in determining these rates. The data represent the last three sessions under each of the three timeout durations for DRL 20-sec and DRL 30-sec. There appeared to be little effect due to the duration of the timeout, since no consistent trends existed within or across birds for either DRL value. The rates of responding for each bird were quite similar across timeout durations within DRL 20-sec and DRL 30-sec respectively. The rates of reinforcement showed similar variability for each bird. Inspection of the IRT distributions for these same conditions indicated a comparable degree of similarity.

Table 1

The response rates and reinforcement rates for the last three days combined for each of the timeout values under both DRL 20-sec and DRL 30-sec.

Schedule	Responses/Min			Reinforcements/Min		
	#21	#23	#45	#21	#23	#45
DRL 20-sec						
5-sec timeout	5.8	4.5	3.3	0.17	0.39	1.33
10-sec timeout	5.5	4.1	3.2	0.10	0.56	1.15
20-sec timeout	5.5	4.1	3.4	0.09	0.67	1.05
DRL 30-sec						
5-sec timeout	4.8	3.3	2.3	0.03	0.23	0.71
10-sec timeout	3.9	3.1	2.7	0.05	0.31	0.72
20-sec timeout	4.5	3.4	2.5	0.05	0.23	0.62

Figure 1 shows the percentage of responses within 10-sec IRT categories for the five conditions of the experiment. Unreinforced responses are shown in black and reinforced responses in white. The data represent the last five days combined for DRL 20-sec before the start of the timeout procedure (DRL 20 BEFORE TO), the last five days under DRL 20-sec after the timeout procedure was terminated (DRL 20 AFTER TO), and the last five days under DRL 30-sec just before the timeout procedure was introduced at that value (DRL 30 BEFORE TO). Since the results of Table 1 indicated little difference among the timeout durations, these data were combined. Thus, the data for DRL 20-sec and DRL 30-sec during timeout represent nine days. The effect of the timeout procedure at DRL 20-sec was to decrease the percentage of short IRTs in the 0- to 10- sec category while

increasing those from 11 to 20 sec, as well as increasing the percentage of reinforced responses. The overall effect was a shift of the distributions toward longer IRTs. After removal of the timeout condition, the distributions shifted back toward the initial values. As in the first condition, a large percentage of IRTs occurred from 0 to 10 sec, with a smaller percentage from 11 to 20 sec.

Table 2 presents the rates of responding and rates of reinforcement for the data shown in Fig. 1. It is evident that the rate of responding during the timeout condition was greatly depressed over baseline performance under DRL 20-sec, while the reinforcement rate increased for each bird. After the timeout procedure was removed, performance tended to shift back to baseline, although the response rates remained somewhat lower and reinforcement rates somewhat higher than during the initial condition.

Fig. 1. The percentage of total responses falling in each 10-sec IRT category. The five conditions of the experiment are shown for each bird going from left to right. IRTs which met the reinforcement criterion are indicated by white bars and unreinforced IRTs by black bars. For those conditions during which the timeout procedure was in effect, the data are combined over the last three days under each of the three timeout values. For the remaining conditions, the data represent the last five days combined.

Table 2

The response rates and reinforcement rates for the five conditions of the experiment. For those conditions during which the timeout procedure was in effect, the data are combined over the last three days under each of the three timeout values. For the remaining conditions, the data represent the last five days combined.

Schedule	Responses/Min			Reinforcements/Min		
	#21	#23	#45	#21	#23	#45
DRL 20-sec						
Before timeout	9.7	8.8	8.9	0.04	0.24	0.32
During timeout	5.6	4.2	3.3	0.12	0.51	1.16
After timeout	6.8	7.8	5.4	0.06	0.38	0.97
DRL 30-sec						
Before timeout	6.0	5.6	4.6	0.02	0.15	0.61
During timeout	4.4	3.2	2.5	0.04	0.25	0.68

Figure 1 shows that changing the schedule to DRL 30-sec shifted the distribution toward longer IRTs when compared to the DRL 20-sec performance that preceded it. For Pigeon 21, there was a decrease in the percentage of IRTs from 0 to 10 sec with a slight increase in the next two categories. The percentage of IRTs from 0 to 20 sec decreased for Pigeon 23 while the percentage of IRTs from 21 to 40 sec showed a corresponding increase. Pigeon 45 showed a slight increase in the first category, a large drop in the second category, and a moderate increase in the next two IRT categories. The rates of responding for this condition (Table 2) indicate a moderate but consistent decrease. The timeout procedure under DRL 30-sec again shifted the IRT distributions in a manner similar to that at DRL 20-sec. For each bird the percentage of IRTs from 0 to 10 sec decreased when compared to prior responding at DRL 30-sec, while the percentage from 21 to 30 sec and from 31 to 40 sec all increased. Table 2 again shows a further decrease in the rate of responding along with an increase in reinforcement rate for this condition.

Figure 2 shows the IRTs/OP curves for the five conditions of the experiment. Both Anger (1956, 1963) and Reynolds (1968) have argued that IRTs/OP, a conditional probability statistic, is the most sensitive measure for detecting a temporal discrimination. Each point on the curve answers the question: given that the subject waited at least t sec to respond, what was the probability that a response would occur in the $t+2$ sec IRT category? This type of

analysis has some desirable characteristics. First, the probability of responding in the longer intervals is not affected by the large number of IRTs which fall in the first category. Second, if the subject were responding randomly with respect to time, the IRTs/OP statistic would be approximately equal for all points.

The curves on the left side of Fig. 2 show performance under the three conditions of DRL 20-sec. Although the curves show some dissimilarities across birds, distinctive trends stand out. The curves for DRL 20-sec before any manipulations show for each bird a high probability of responding in the shortest IRT category, followed by a sharp drop for the 2 to 4-sec category, and then a steady rise. All reached an initial peak at about 8 sec and fluctuated about that value at longer IRTs, approximating equality. This is in marked contrast to the curves representing responding under the timeout condition at DRL 20-sec.

Fig. 2. IRTs/OP values as a function of 2-sec IRT categories. The numbers on the abscissa represent the lower limit of each 2-sec IRT category. The curves on the left side of the figure show performance for the three conditions under DRL 20-sec for each bird while those on the right side show performance under the two DRL 30-sec conditions. The data were combined in the same way as for Fig. 1. No IRTs/OP values were computed where the opportunities were fewer than 20.

The probability of a response in the shortest category was near zero for each bird, increasing monotonically to a peak probability just before the reinforced value for Pigeon 21, and a peak for Pigeon 23 and Pigeon 45 near 24 sec. The curves for all birds still showed the presence of a temporal discrimination after the timeout condition was terminated at DRL 20-sec, although, in general, it was not as sharp. The curve for Pigeon 45 was quite similar to the curve for responding during the timeout procedure, while the data for the other birds appeared to be more similar to the baseline condition.

The curves for DRL 30-sec are shown on the right side of Fig. 2. For all three birds, the curves representing responding soon after exposure to DRL 30-sec shifted toward longer IRTs. Compared to the last five days of DRL 20-sec responding, these curves increased at a slower rate and peaked somewhat later. The effect of the timeout was not as striking at DRL 30-sec as it had been at DRL 20-sec. As before, responses falling into the first category were greatly suppressed. For the remaining part of the curve, the timeout procedure had a fairly large effect on the responding of Pigeon 21, a somewhat smaller effect on Pigeon 23, and virtually no effect on Pigeon 45.

DISCUSSION

Response-produced timeout suppressed responding maintained on either a DRL 20-sec or DRL 30-sec schedule with the timeout values employed here. It appears that the degree of suppression was roughly similar to the effect achieved with low to moderate intensities of shock (up to 60 v) by Holz and Azrin (1963) and Holz *et al.* (1963) under a DRL 30-sec schedule. Timeouts greatly suppressed the percentage of responses with short IRTs under both schedules, and the shift in the IRT distribution was similar to the shift which has been produced with shock. These results are also in accord with McMillan (1967), who found that response-produced timeouts of 60 to 90 sec and response-produced shock of 1 to 2 ma suppressed VI responding in monkeys to a similar degree.

There is also a suggestion in the results that the timeout procedure at DRL 20-sec produced a slight improvement in performance after it terminated, although the experiment was not

specifically designed to explore this question. Table 2 shows that all birds had a lower response rate and higher reinforcement rate after the timeout procedure under DRL 20-sec compared to baseline performance. The IRTs/OP curves of Fig. 2 show that the orderly temporal discrimination developed by Pigeon 45 while the timeout procedure was in effect was maintained in a similar manner after this procedure was terminated. This is in contrast to baseline performance which did not show an orderly temporal discrimination. Pigeons 21 and 23 did not show such accurate timing behavior after the timeout procedure was terminated. The IRTs/OP curves for these birds fell in between the curves representing baseline performance and performance during the timeout procedure. It is possible that this slight improvement was due to extended training on the schedule, although Reynolds (1964b) found that pigeons exposed to a DRL 20-sec schedule for 119 sessions showed no noticeable improvement in performance after about the sixth session. In light of the general finding that pigeons respond at a rate higher than specified by the contingencies of DRL schedules of 20 sec or longer, it may be worthwhile to investigate further the effect of more extended use of the timeout procedure or its earlier introduction into training than was used here.

The data also indicate an adjustment to DRL 30-sec soon after exposure to that delay interval. It is clear from Fig. 1 that the IRT distributions shifted toward longer IRTs, indicating adjustment in response to a change in the schedule requirements. The IRTs/OP curves also shifted in a manner indicating adjustment while still showing the existence of a temporal discrimination. Staddon (1965) found that, when the schedule was changed from DRL 20-sec to DRL 30-sec after 220 sessions of DRL responding, two of three birds increased their rate of responding, indicating a lack of adjustment. In the present experiment, all three birds decreased their rate of responding under DRL 30-sec when compared to the DRL 20-sec which preceded it.

There is some discrepancy between Fig. 1 and Fig. 2 with regard to the effect of the timeout condition at DRL 30-sec. Figure 1 suggests a rather large effect, since the distributions have shifted toward longer IRTs; Fig. 2 shows a relatively small effect. The discrep-

ancy lies in the fact that eliminating the IRTs from 0 to 2 sec has no effect on the calculation of the rest of the points using the IRTs/OP statistic, while eliminating these short IRTs inflates the relative percentage of responses falling into categories above 10 sec in Fig. 1. Thus, the major effect of the timeout procedure under DRL 30-sec was virtually to eliminate the shortest IRTs. The degree to which the timeouts affected the rest of the IRTs was a function of the degree to which the subject had adjusted to the schedule; as the degree of adjustment increased, the effect of the timeout decreased. The comparison of these two methods of presenting the data indicates the care which must be taken in analyzing performance on time-contingent schedules such as DRL and Sidman avoidance.

REFERENCES

- Anger, D. The dependence of interresponse times upon the relative reinforcement of different interresponse times. *Journal of Experimental Psychology*, 1956, 52, 146-161.
- Anger, D. The role of temporal discrimination in the reinforcement of Sidman avoidance behavior. *Journal of the Experimental Analysis of Behavior*, 1963, 6, 477-506.
- Holz, W. C. and Azrin, N. H. A comparison of several procedures for eliminating behavior. *Journal of the Experimental Analysis of Behavior*, 1963, 6, 399-406.
- Holz, W. C., Azrin, N. H., and Ulrich, R. E. Punishment of temporally spaced responding. *Journal of the Experimental Analysis of Behavior*, 1963, 6, 115-122.
- Leitenberg, H. Is time-out from positive reinforcement an aversive event? *Psychological Bulletin*, 1965, 64, 428-441.
- McMillan, D. E. A comparison of the punishing effects of response-produced shock and response-produced time out. *Journal of the Experimental Analysis of Behavior*, 1967, 10, 439-449.
- Reynolds, G. S. Accurate and rapid reconditioning of spaced responding. *Journal of the Experimental Analysis of Behavior*, 1964, 7, 273-276. (a)
- Reynolds, G. S. Temporally spaced responding in pigeons; development and effects of deprivation and extinction. *Journal of the Experimental Analysis of Behavior*, 1964, 7, 415-421. (b)
- Reynolds, G. S. *Primer of operant conditioning*. Glenview, Ill.: Scott, Foresman, 1968.
- Rilling, M. Number of responses as a stimulus in fixed interval and fixed ratio schedules. *Journal of Comparative and Physiological Psychology*, 1967, 63, 60-65.
- Staddon, J. E. R. Some properties of spaced responding in pigeons. *Journal of the Experimental Analysis of Behavior*, 1965, 8, 19-27.
- Wilson, M. P. and Keller, F. S. On the selective reinforcement of spaced responding. *Journal of Comparative and Physiological Psychology*, 1953, 46, 190-193.

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