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THE EFFECT OF DRUGS ON A FIXED-RATIO PERFORMANCE SUPPRESSED BY A PRE–TIME-OUT STIMULUS[1,2]

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Pecking was reinforced by a fixed-ratio schedule with food, and responses during a red light produced a time out. If the bird did not respond during the red light, the light terminated and the bird could complete the FR schedule of positive reinforcement uninterrupted. The bird stopped responding during the red light sufficiently to avoid most of the possible time outs. In general, the pre–time-out stimulus suppressed responding more when the FR schedule was large than when it was small. The occurrence of the pre–time-out stimulus in the fixed ratio produced FR strain and extreme curvature atypical of normal fixed ratios of this size. Amobarbital, pentobarbital, chlorpromazine, and *d*-amphetamine injected when the FR performance was strained by the pre–time-out procedure produced marked increases in responding. The drug administration lowered the rate of responding only at larger doses; and then this occurred predominantly just after the injection.

Under several conditions, the stimulus preceding a time out from positive reinforcement may suppress responding on the base-line schedule as it does when a stimulus precedes an electric shock (Estes & Skinner, 1942). Herrnstein (1955) and Ferster (1958, 1960) have described the procedures. In all of the earlier experiments studying the effect of a pre–time-out stimulus, the base line was a variable-interval schedule of positive reinforcement. Furthermore, the procedure had little effect on responding elsewhere than in the pre–time-out stimulus, except, perhaps, for some frequent pausing (Ferster, 1958). The pausing was difficult to interpret because such a deviation may be a result of other conditions. However, in this experiment, the pre–time-out stimulus was imposed on a fixed-ratio base line; and the procedure was similar to one used earlier by Ferster (1958), in which no time out occurred in the absence of responding in the critical part of the pre–time-out stimulus. A fixed-ratio (FR) schedule was used for several reasons. First, because rate changes are easier to identify in a fixed-ratio rather than a variable-interval (VI) schedule, any disruptions in the base line produced by the pre–time-out stimulus would be much easier to detect. Second, in an FR, changes in the rate of responding alter the frequency of reinforcement, so that any variable that increases pausing or lowers the rate of responding can be used to produce low frequencies of reinforcement. In contrast, in VI, the frequency of reinforcement can be altered significantly at only extreme rate changes. Third, in an FR, the probability of a response being reinforced does not increase during a pause. Consequently, if pausing should emerge in the presence of a pre–time-out stimulus, the pause would not be counteracted by the increased probability of reinforcement resulting from the interval basis of the schedule. Finally, reinforcement under FR ratio schedules more frequently occurs while the rate of responding is high. Because the increase in the number of responses emitted may function as a conditioned reinforcement, at any point in a fixed ratio the conditioned reinforcement provides a basis for the reinforcement of high rates. This final factor would impede the development of pausing during the pre–time-out stimulus to the extent that the FR schedule generates sustained rates of responding under normal conditions. Usually, once the ratio has begun, it is completed. On the other hand, because reinforcement always occurs at high rates, any pausing once begun might be maintained.

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PROCEDURE

The experiments were carried out in a standard experimental space with one key which would be illuminated red or green. The subjects were two White Carneaux cock pigeons.

General Procedure

The pre–time-out stimulus, a red light, occurred after a response in the fixed ratio; for example, the red light might come on after the fifth response following reinforcement. Responses during the first part of the warning stimulus continued to advance the fixed ratio, and were not followed by a time out. However, responses during the final part of the pre–time-out stimulus were followed by a time out. If the bird did not respond in the last part of the pre–time-out stimulus, the pre–time-out stimulus terminated and the FR requirement for the food-magazine operation could be completed. Thus, no food reinforcement was possible unless the bird allowed the pre–time-out stimulus to terminate without a response.

Variations in Procedure

In the first exposure to the time-out contingencies, both animals had already achieved a stable FR 85 performance. The pre–time-out stimulus occurred after the 50th response after reinforcement in every third FR segment. The maximum duration of the pre–time-out stimulus was 3 sec (2 + 1), but only responses in the final second produced a 20-min time out. Because the two birds' performances differed under the time-out procedure, all of the major variables in the procedure were adjusted to make the deviant bird conform.

Schedule of Occurrence of the Pre–time-out Stimulus. In the early stages of the experiment, the pre–time-out stimulus was made to occur more and more frequently. First, it occurred in each fixed-ratio segment. Then, the fixed ratio was reset following each time out. Finally, every time a response in the pre–time-out stimulus was followed by a time out, the very next response the animal made reintroduced the time out, and the fixed ratio could not be completed until the bird ceased responding during the pre–time-out stimulus.

The Time Out. Whenever the frequency of time outs was very high, particularly with Bird 4Y, the duration of the time out was reduced so that a sufficient number of reinforcements could occur for the bird to be exposed to the contingencies. As the pre–time-out procedure produced suppression during the pre–time-out stimulus, the duration of the time out was increased to the values noted below.

Duration of the Pre–time-out Stimulus. The duration of the pre–time-out stimulus was kept very small until it suppressed responding, at which point it was gradually increased. This procedure was used on the assumption that a gradual increase in the duration of the pre–time-out stimulus is a condition which will produce suppression, whereas a sudden exposure to a long duration of the pre–time-out stimulus will not.

The Size of the Fixed Ratio. Particularly with Bird 4Y, the size of the fixed ratio was increased in order to produce suppression in the pre–time-out stimulus. As the results indicated, suppression with Bird 4Y was easier to achieve at large fixed ratios.

Final Procedure After the Pre–time-out Stimulus Suppressed the Base-line Performance in Both Birds

The main data to be reported is the final effect of the procedures rather than the transitory states and the effects of the intermediate procedures. We did not study these intermediate states thoroughly enough so we could be sure which of the early procedures were essential for the final state.

Bird 3Y. In the first part of the experiment, the maximum duration of the pre–time-out stimulus was 3 sec, and responses in the first two sessions advanced the fixed ratio but had no effect on the time out. Responses in the final 1 sec produced a 20-min time out, and the pre–time-out stimulus occurred following the first response in the fixed ratio. When the position of the pre–time-out stimulus in the fixed ratio was varied, the maximum duration of the pre–time-out stimulus was increased to 9.5 sec, and only responses in the final 2 sec produced a 10-min time out. During the intermediate stages of the experiment, the size of the fixed ratio was varied between 60 and 210. However, in the final procedure, in which the position of the pre–time-out stimulus was varied, the fixed ratio remained at 100.

Bird 4Y. The size of the fixed ratio varied from 100 to 250. The maximum duration of the pre–time-out stimulus was 4 sec, and a

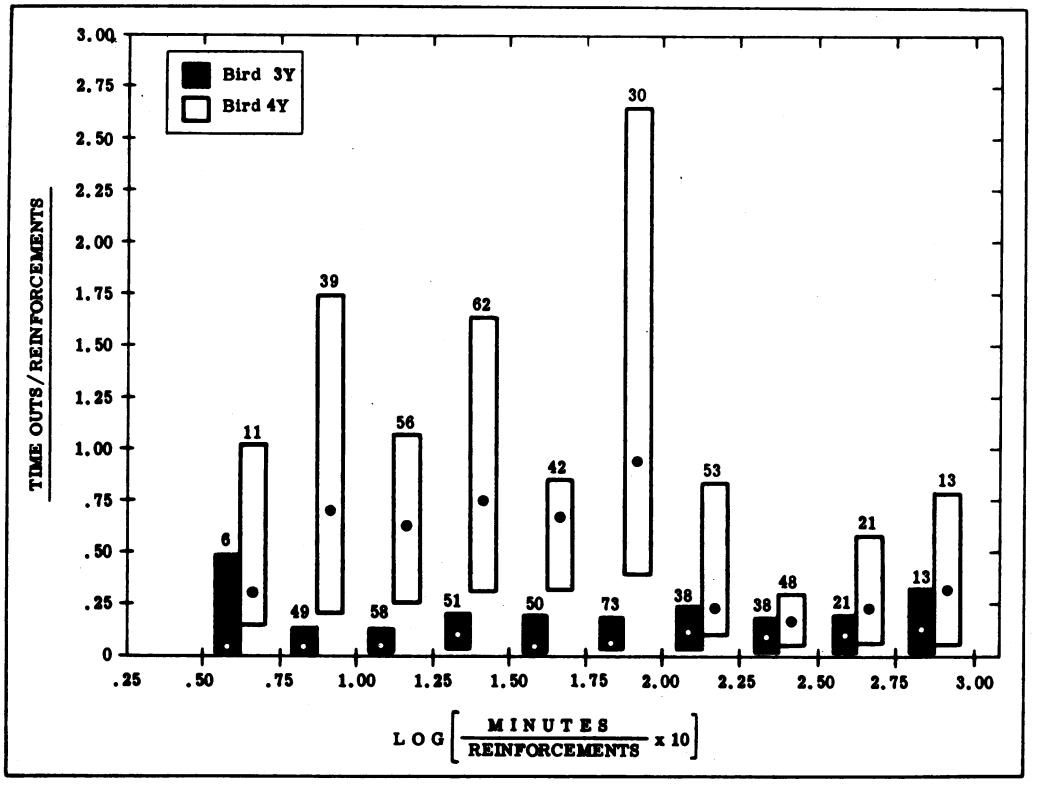

Fig. 1. The number of time outs in the pre–time-out stimulus is given as a function of the amount of strain in the fixed ratio (time per reinforcement). Each point is the median time-out level of experimental sessions falling in a given class interval of fixed-ratio pausing. The bar gives the interquartile range, and the number over each bar gives the number of sessions falling into each class interval.

3-min time out followed only those responses in the final 2 sec.

RESULTS

Figure 1 illustrates the main difference between the two birds, whose preformances were recorded after considerable exposure to the pre–time-out stimulus. The data here include only the procedure in which the pre–time-out stimulus followed the first response in the fixed ratio and reappeared after each time out. The graph shows the number of time outs (expressed as time outs per reinforcement) occurring as a function of the amount of fixed-ratio straining. Each point gives the median of the session; the bar gives the interquartile range; and the number over each bar is the number of experimental sessions falling in the indicated class interval. This figure shows that Bird 3Y's tendency to respond in the pre–time-out stimulus was much lower than that of Bird 4Y. The median number of time outs per reinforcement never exceeds 0.1 time out per reinforcement. Also, the degree of suppression by the pre–time-out stimulus does not appear to depend upon the amount of fixed-ratio straining, except, perhaps, that the pre–time-out responding has some slight tendency to increase at extreme degrees of fixed-ratio strain. However, Bird 4Y showed suppression only when the base-line, fixed-ratio, performance showed considerable strain. Time outs occurred in less than 50% of the pre–time-out stimuli only when the mean time per reinforcement exceeded 10 min. Nevertheless, the data in the first bar are an exception. This was the only phase of the experiment in which the pre–time-out stimulus suppressed responding even though the bird was responding at a high rate. This level of suppression occurred at an early phase of the experiment, when the size of the fixed ratio varied between 120 and 140 and the

performance was very well sustained. Thereafter, the size of the ratio was reduced to FR 50, and the amount of pre–time-out stimulus responding increased greatly. After the exposure to FR 50 and the loss of suppression, the pre–time-out stimulus suppressed responding only when the size of the fixed ratio and other conditions of the experiment were such as to produce considerable straining in the base-line performance. Even after this bird developed suppression in the pre–time-out stimulus with large fixed ratios, decreasing the size of the fixed ratio again increased the number of times out.

The Effect of the Pre–time-out Stimulus on the FR Performance

Bird 3Y. The predominant effect of the pre–time-out stimulus on the fixed-ratio performance was an increase in pausing after reinforcement, scalloping rather than the usual "square" FR performance, and variability in the terminal rate of responding. Figure 2 contains all of the segments from an experimental session. These segments are arranged in order of length of pause, and the numbers on each give the actual order of occurrences. The schedule of food reinforcement was FR 210, and the pre–time-out stimulus occurred after the first response for 4 sec. Only responses in the first 2 sec produced time outs; and after a time out, the pre–time-out stimulus reappeared with the next response. Segment 7 (high) and Segment 8 (low) illustrate the large variability in the terminal rate of responding in the FR. Scattered responding occurred throughout many of the strained ratios, as, for example, in Segments 15 and 19 at the top of the figure. The shift to the terminal rate of responding was sometimes abrupt, as in Segment 17; but frequently it was gradual, as in Segment 12, where the performance is similar to that under an FI schedule.

Even after the size of the fixed ratio was reduced to 90, the extreme pausing, curvature, and intermediate rates of responding continued. Figure 3 shows a performance when the schedule of reinforcement had been FR 90 for 7 sessions following 63 sessions of continuously downward adjustment of the fixed ratio. The pre–time-out stimulus still occurred after the first response in the fixed ratio for a maximum duration of 4 sec. The entire ex-

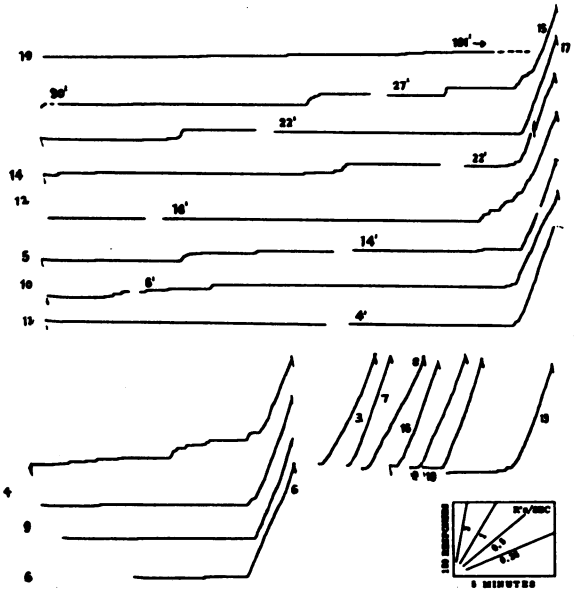

Fig. 2. Final performance on FR 210 showing extreme pausing after reinforcement and a wide range of terminal rates of responding. The pre–time-out stimulus (TO 20) occurred after the first response in the FR for a maximum of 4 sec. Time outs followed only responses in the last 2 sec of the 4-sec pre–time-out stimulus.

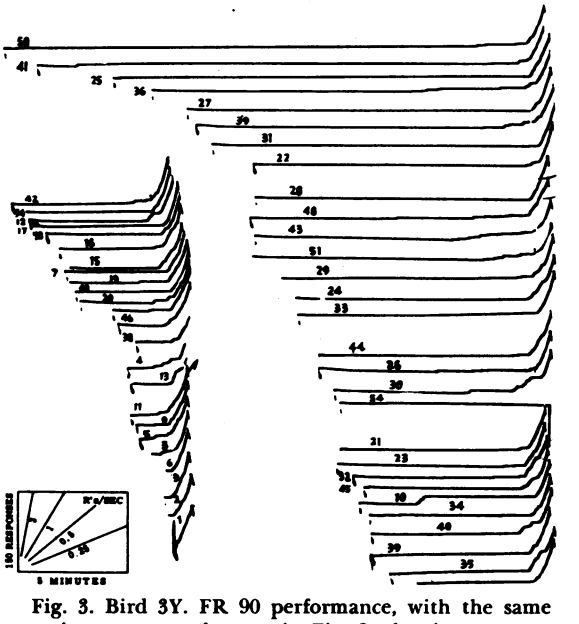

Fig. 3. Bird 3Y. FR 90 performance, with the same pre–time-out procedure as in Fig. 2, showing extreme curvature. The segments are arranged in order of length of time, and the actual order of occurrence is given by the number above each segment.

perimental session is again presented, with each FR segment arranged in order of the length of time required to complete the fixed ratio. There was still considerable pausing (15 min in the top two curves), and the terminal rate of responding doesn't exceed 2 responses per sec except at the very end of the FR segment. Frequently, the rate did not exceed 1 response per sec (Segment 48). In general, the over-all rate of responding was high at the start of the session but fell during the session, as often happens with strained fixed ratios. Most of the segments show curvature and scalloping more nearly resembling a fixed-interval performance than that of a fixed ratio.

At one stage of the experiment, this bird stopped responding during the pre–time-out stimulus without extreme curvature or intermediate rates of responding. Figure 4 shows such a performance for Bird 3Y when the fixed ratio was 100 and the pre–time-out stimulus was 4 sec. Long pauses followed reinforcement, without disruption of the normal

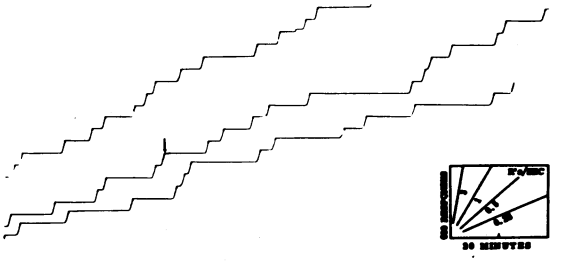

Fig. 4. Bird 3Y. Performance on FR 100 with a 3-sec pre–time-out stimulus (TO 20) showing considerable pausing but minimal curvature. The pre–time-out stimulus occurred after the second response in the fixed ratio.

fixed-ratio pattern of responding. Only one time out (at the arrow) occurred during the session. The pause after reinforcement frequently lasted up to 20 min; but once responding began, the bird frequently reached the terminal rate of responding immediately. Occasional curvature did occur, however, as in the fifth segment from the end of the session.

Bird 4Y. Figure 5 shows two consecutive sessions of Bird 4Y's performance on FR 140. The pre–time-out stimulus occurred after the first response in the FR for a maximum duration of 4 sec, and time outs occurred during the final 2 sec. The pre–time-out stimulus reappeared on the first response following a time out (TO 3). Bird 4Y sustained responding throughout the experiment at high fixed ratios better than Bird 3Y. The performance recorded in Fig. 5 occurred just after responding in the pre–time-out stimulus fell to the point where time outs occurred only occasionally. During the next 15 sessions, the median number of time outs per reinforcement was

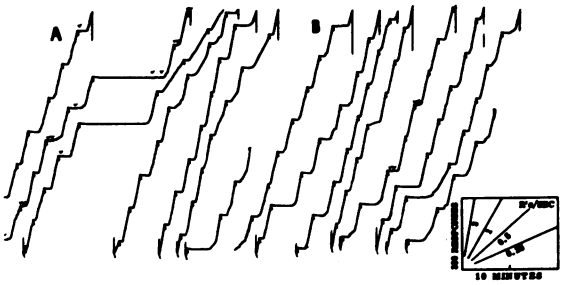

Fig. 5. Bird 4Y. Two consecutive daily sessions on FR 140 illustrating the early development of suppression of responding by the warning stimulus. The pre–time-out stimulus followed the first response in the fixed ratio for a maximum duration of 4 sec. Only responses in the final 2 sec were followed by a time out (3 min).

0.30; $Q_1 - Q_3$ was 0.10 to 0.91; and the range was 0.0 to 10.40. Records A and B are two consecutive daily sessions illustrating the range of performances during this phase of the experiment. Record A shows 16 time outs (at the arrows) compared with 4 in Record B. Although the curvature was much less than with Bird 3Y, variations in the magnitude of the running rate were extreme, as in the last three reinforcements of the third segment of Record A, for example. In spite of the high over-all rate of responding, most of the pre–time-out stimuli occurred without time outs.

Figure 6 illustrates the extreme of the effect of the pre–time-out stimulus on the fixed-ratio performance, 17 sessions after Fig. 5

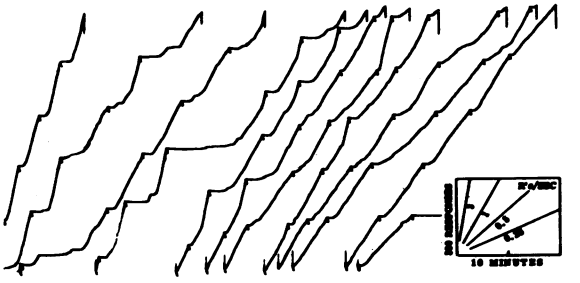

Fig. 6. Bird 4Y. An FR 230 performance showing a predominance of intermediate rates of responding. The pre–time-out stimulus procedure was the same as in Fig. 5.

when the size of the fixed ratio had reached 230 and when responding had virtually ceased during the critical part of the pre–time-out stimulus. There were no time outs during the session, although 21 responses occurred during the first 2 sec of the 4-sec, pre–time-out stimulus. Occasional instances of extreme curvature appeared; however, the main effect of the pre–time-out stimulus on the fixed-ratio responding was sustained responding at intermediate rates that is more characteristic of interval than ratio schedules. Occasional instances of high rates of responding immediately preceding the reinforcement still occurred, as well as typical "normal" fixed-ratio segments. An example is in the fourth recorder excursion.

Removal of the Pre–time-out Stimulus for Bird 3Y

Early in the experiment, when the pre–time-out stimulus was suppressing responding on FR 60 and also producing considerable strain and curvature in the base-line FR performance, the pre–time-out stimulus was removed for 13 sessions. During this period, there was no indication that the base-line performance was returning to normal, and the pre–time-out procedures were again resumed. Once more, we attempted to recover a normal fixed-ratio performance by discontinuing the pre–time-out procedure after the drug experiments reported in Experiment II. But the curvature did not disappear until this bird had prolonged exposure (151 sessions) to very small fixed ratios. During 25 sessions on FR 100, we gave five consecutive injections of chlorpromazine to see whether the increased rates of responding under the drug (Experiment II) would continue after drug administrations were discontinued. The injections produced normal FR rates of responding, but the base line returned to its previously strained condition when the drug was discontinued. For the next 35 sessions, the size of the fixed ratio was progressively increased from FR 40 to FR 130. After these procedures did not change the bird's performance, the fixed ratio was again decreased to FR 30, and the program of increasing the size of the FR to FR 100 was made even more gradual (over 90 sessions). Reinforcement was maintained at each value of the fixed ratio until it was sustained normally, and then it was increased. Any time rate changes atypical of a normal FR schedule occurred, the fixed ratio was kept at that value or decreased. And the curvature and intermediate rates of responding disappeared only toward the end of this 90-session period.

Position of Pre–time-out Stimulus in the Fixed Ratio

While Bird 4Y's procedures were being adjusted to produce suppression during the pre–time-out stimulus, the position of the pre–time-out stimulus in the FR 100 food schedule was varied for Bird 3Y.

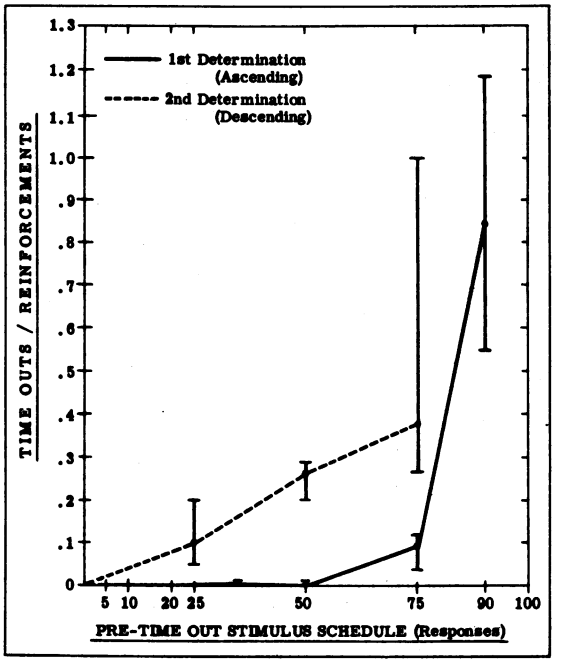

Fig. 7. Bird 3Y. FR 100, 4-sec pre–time-out stimulus, TO 20. The frequency of time outs was a function of the position of the pre–time-out stimulus in the fixed ratio. The determinations were made in order, first ascending then descending. The median and interquartile range are given for the last five sessions on each value of the independent variable.

Figures 7 and 8 summarize the over-all rate of responding and frequency of time outs, respectively, as the position of the pre–time-out stimulus was varied. The maximum duration of the pre–time-out stimulus was 9.5 sec (7.5 + 2) to 10. The first determination was made with the pre–time-out stimulus after the first response in the fixed ratio. After the performance stabilized at this value, the procedure was altered to produce the pre–time-out stimulus after the 5th response in the fixed ratio; then, the

10th, 20th, 35th, 50th, 75th, and 90th response (10 responses before the reinforcement). Some of the original values were then recovered in a descending series as given in the graphs. The pre–time-out stimulus suppressed responding more when it occurred early in the fixed ratio. When the pre–time-out shimulus occurred after the 75th response, responding in the pre–time-out stimulus increased. After the 90th response, responding in the pre–time-out stimulus increased to produce the highest level of time out that this bird had shown since the control by the pre–time-out stimulus was first established. The increased pre–time-out responding continued even when the pre–time-out stimulus was moved to a position earlier in the fixed ratio during the descending series of measurements. However, suppression finally became complete when the pre–time-out stimulus occurred again after the first response.

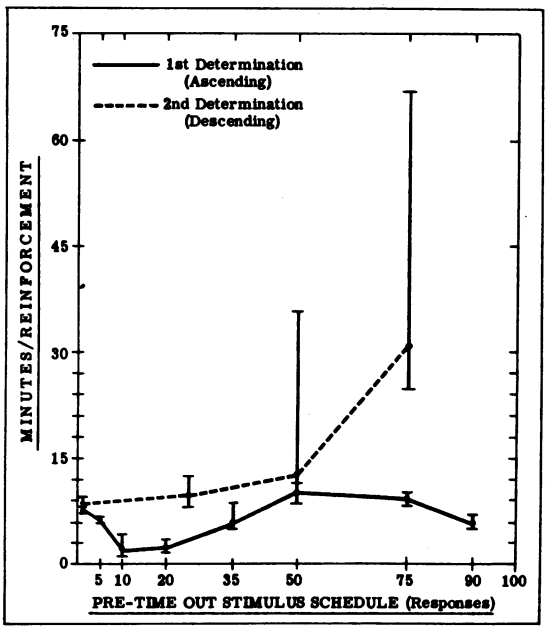

Fig. 8. Amount of fixed-ratio strain as a function of the position of the pre–time-out stimulus in the fixed ratio. The determinations were made in order, first ascending then descending. The median and interquartile range are given for the last five sessions on each value of the independent variable.

Moving the position of the pre–time-out stimulus toward the end of the fixed ratio did not decrease the over-all rate of responding until it occurred after the 75th response in the fixed ratio in the descending series. The over-all rate fell, probably as a cumulative result of the exposure to FR 90 and FR 75; but, thereafter, it reached essentially the base-line values at FR 50, 25, and 1. The reliability of the measurements is sufficiently good that the decrease in rate of responding on FR 5 and 10 is significant. Possibly, there is an optimal point for interrupting the fixed ratio with minimum disruption of the FR performance: It is early enough in the fixed ratio so that the tendency to respond is not so high as to make it virtually impossible to stop responding in the pre–time-out stimulus; yet, it is far enough into the fixed ratio so that the disposition to respond is enough for the performance to be sustained.

EXPERIMENT I: DISCUSSION

These experiments confirm the observation that when the pigeon can avoid a time out if it stops responding in the warning signal, the pre–time-out stimulus controls a lower rate of responding. Control by the pre–time-out stimulus was generally easier to establish with large fixed ratios; but once the warning stimulus suppressed the bird's responding, it continued to do so even after the size of the fixed ratio was reduced, particularly for Bird 3Y. The two birds differed markedly in the conditions under which the early control of the pre–time-out stimulus developed. The control developed readily in Bird 3Y and remained intact, regardless of the size of the fixed ratio. But for Bird 4Y, which had generally higher rates of responding, the pre–time-out stimulus suppressed responding only after the performance was weakened following the increase in the fixed ratio to values producing extreme amounts of pausing.

Even when the pre–time-out stimulus occurred only after the first response in the fixed ratio, the normal FR performance was grossly disrupted for the remainder of the fixed ratio. With both birds, a typically long pause occurred after reinforcement, as well as extended curvature more typical of fixed-interval than of fixed-ratio schedules. The order of magnitude of disruption of the FR pattern of responding recorded in this experiment does does not occur under simple FR schedules of

reinforcement, except perhaps as a transitory condition. Prolonged curvature was recorded, for example, under a tandem fixed-ratio, fixed-interval schedule (Ferster & Skinner, 1957) preliminary to almost complete cessation of responding. Equally significant are the large order-of-magnitude declines in the terminal rate of responding for Bird 4Y, which would suddenly respond evenly at only 1 response per sec throughout the ratio. This gross disruption of the base-line performance is further evidence of the aversiveness of the pre–time-out stimulus, and confirms the previous findings that time out from even relatively unfavorable (low frequency of reinforcement) schedules of reinforcement continues to suppress responding (Ferster, 1960). For Bird 3Y, the suppression by the pre–time-out stimulus disappeared when this stimulus occurred toward the end of the fixed ratio. This bird received many time outs because it responded during the warning stimulus. In general, the closer the warning stimulus was to the end of the ratio, the more difficult it was for the bird to stop responding.

Even under those conditions in which the bird showed a very low disposition to peck (*e.g.*, in an 8-hr experimental session when only two or three fixed reinforcements might occur), the normal FR responding ceased whenever the pre–time-out stimulus occurred. Thus, the pre–time-out stimulus apparently will more easily suppress responding when the disposition to respond generated by the base-line schedule of positive reinforcement is low.

When the base-line schedule of reinforcement is variable-interval, the small size of the pre–time-out stimulus might frequently fall within normal inter-response times. Hence, the frequency of responding in the pre–time-out stimulus might fall solely because of the decreased rate of responding. In ratio schedules, however, regardless of how low the over-all rate of responding may be, local rates of responding remain high. Therefore, the fact that the pre–time-out stimulus was response-contingent guaranteed that it would be programmed regularly whenever there was some substantial disposition to respond. Thus, the low rate of responding in the pre–time-out stimulus in the FR schedule is a suppression of the bird's performance at a time when it has a substantial frequency of responding. If the pre–time-out stimulus were programmed on a time rather than a fixed-ratio basis, it would occur most frequently during the long pauses of the strained fixed ratio. Thus, it would not be possible to know if the low rate is due to the pause generated by the base-line schedule of positive reinforcement or the suppression by the time-out procedure, if the pre–time-out stimulus were programmed as a temporal basis.

Because the probability of a response being reinforced does not increase with passage of time in fixed-ratio schedules, long pauses are not followed by reinforced responses as they are in variable-interval schedules. Under interval schedules of reinforcement, the probability that the next response will be reinforced increases in a pause and might lead to an increase in the rate of responding in the warning stimulus in spite of the ensuing time-out (Ferster, 1958, 1960). A similar factor, counteracting the possible aversive effects of the time out, might also operate in ratio base lines, even though the probability of reinforcement does not increase with pauses. In the FR schedule, the very high rate of responding and strong over-all disposition to peck generated by the conditioned reinforcement of increased number of responses probably counteracts the zero probability of food reinforcement in the pre–time-out stimulus.

The occurrence of time outs because of responding during the pre–time-out stimulus is related to the general topic of self-control (Skinner, 1957), in which a response is reinforced positively but also has aversive consequences, which may be avoided if the positively reinforced response is withheld. The FR schedule generates a strong disposition to respond that must be reduced during the pre–time-out stimulus. The bird must temporarily cease strong, positively reinforced behavior, especially, for example, when the pre–time-out stimulus appears toward the end of the fixed ratio. Responding during the pre–time-out stimulus seemed to depend on both the over-all disposition to respond as a result of the schedule of positive reinforcement and the aversive consequence of responding in the pre–time-out stimulus.

EXPERIMENT II: INCREASED RESPONDING AFTER INJECTION OF AMOBARBITAL, PENTOBARBITAL, CHLORPROMAZINE, AND, *d*-AMPHETAMINE

Many behavioral experiments with compounds classified pharmacologically as sedatives show both increases and decreases in rate of responding, depending upon both the dose and the nature of the performance (Dews, 1955, 1956, 1958; Morse & Herrnstein, 1956; Verhave, 1959; Boren, 1959; Kelleher & Cook, 1959). Increased rates of responding predominately occur at low doses or when the major effect of the drug is passed and the normal base line is returning. Furthermore, these increased rates of responding are observed in both interval and ratio schedules; however, the effect is usually more pronounced in fixed-interval schedules, since the fixed-ratio performances which were measured were already near maximum rates because of the small size of the ratios. This experiment demonstrates similar increased rates of responding when a low over-all rate of responding on a fixed-ratio schedule is produced by the time-out procedures of Experiment I. We explored a range of doses of amobarbital, and repeated the experiment with pentobarbital, chlorpromazine, and *d*-amphetamine in order to determine what were the characteristics of the behavioral effects with these compounds. Sodium pentobarbital, sodium amobarbital, chlorpromazine, and *d*-amphetamine all produced essentially the same behavioral effects. At larger doses, the behavioral effects of the injection had two phases. First, the pause following the injection reached 120 min after the largest doses. Second, this pause was followed by a period when the extreme pausing (badly strained ratio) yielded to a more typical fixed-ratio performance, with the sustained responding almost immediately after rein-

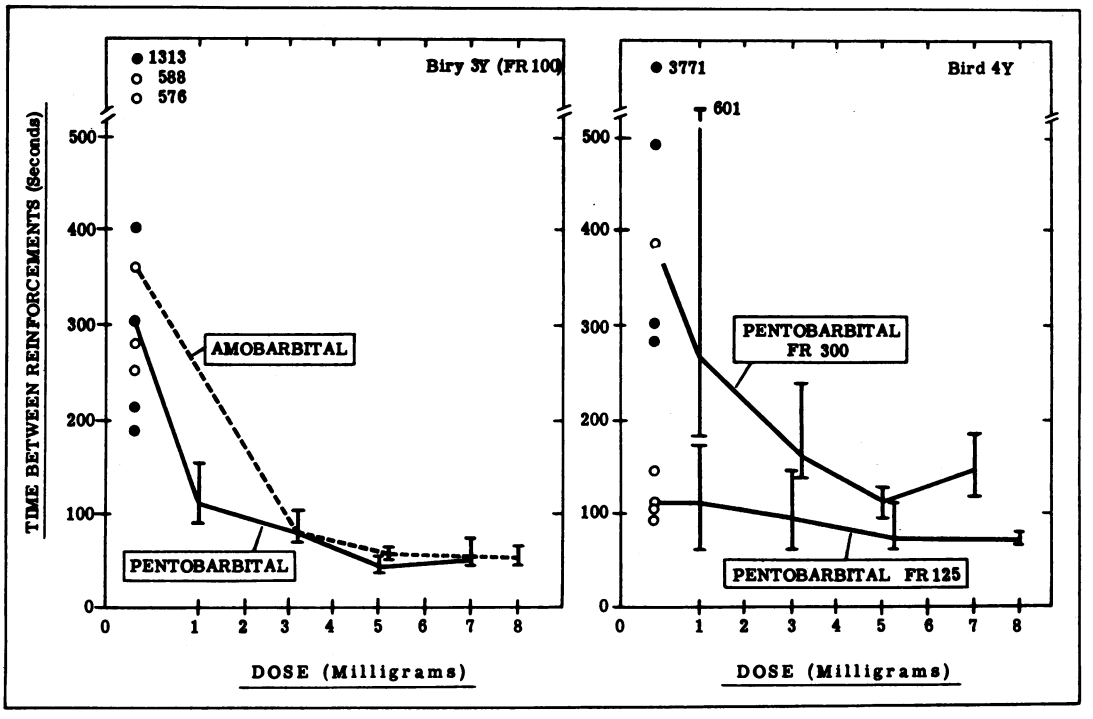

Fig. 9. Effect of amobarbital and pentobarbital on the rate of responding. The ordinate gives the number of seconds taken to complete a single fixed ratio, and the abscissa gives the amount of drug injected. The bird's performance is expressed as the median and interquartile range of the number of seconds required to complete each fixed ratio. The open and closed circles at the extreme left of each panel give the median values for control sessions in which a drug was injected. The curves begin at the median values of the control sessions. The pre–time-out stimulus occurred after the first response in the fixed ratio (7.5 + 2) TO 10 for Bird 3Y and (1 ± 1) TO 3 for Bird 4Y.

forcement continuing until the next reinforcement. Because of the biphasic drug action, the average rate of responding would give a misleading picture of the effect of the drug. The dose-response curve was therefore reported as a median number of seconds required to complete a fixed ratio in the session. Thus, the median and interquartile range of this measurement described the predominant effects of the drug. The remaining aspect of the drug's action can be described by the time following the injection to the time when the bird resumes responding. Drugs dissolved in isotonic saline solution were injected intramuscularly in the breast muscle, and approximately 15 sec elapsed between this injection and the actual start of the session.

Figure 9 gives dose-response curves with sodium amobarbital and pentobarbital for both birds. Each point is the median time per reinforcement for a single experimental session, and the bracket gives the interquartile range. The left panel for Bird 3Y shows dose-response curves for pentobarbital and amobarbital which are similar. The open and closed circles at the left part of the graph give the median number of seconds per reinforcement for each of the experimental sessions preceding the drug injections. The control values are typically variable, ranging from 180 to 1313 sec. The median time for reinforcement decreased to minimum values at the 5-mg dose of the injection drug. Even though the injections disrupted responding completely for as long as 1 or 2 hr at the 7- and 8-mg doses, once the bird began responding the predominant effect of the drug was to increase the rate of responding. As given by the interquartile range around each point, the marked decrease in variability occurred because the birds responded at near the maximum rate. The effect of the pentobarbital injections for Bird 4Y, shown in the right-hand panel of Fig. 9, depends upon the base-line performance. The pentobarbital injections represented by the bottom curve were given early in the experiment, when the schedule of reinforcement was FR 125 and the pre–time-out stimulus had not yet suppressed the bird's performance. Rates of responding increased slightly, particluarly in the interquartile range or the 8-mg doses; but the order of magnitude of the effect of the drug injection was not nearly so large as with Bird 3Y, because the over-all rates of responding were already near maximum. One control point, representing a session when the rate of responding was atypically low, falls in the range of the control points recorded at FR 100. Later, when the size of the fixed ratio was increased to 300, the base-line performance became considerably more strained, as the filled circles at the left show. These circles indicate the control values at this time. The pentobarbital injections given on this base line produced the same results as with Bird 3Y: an increase in rates of responding to near-maximum values. When the base-line schedule was FR 300, Bird 4Y confirmed the reversal of the curve at 7 mg.

Bird 3Y, whose responding ceased almost completely during the pre–time-out stimulus, did not show any increase in pre–time-out responding despite the very large increase in its over-all rate of responding. On the other hand, for Bird 4Y, which responded in the pre-time-out stimulus more than Bird 3Y, the number of time outs under drug also remained approximately the same as during control sessions.

Bird 3Y's data with pentobarbital is shown in more detail in Fig. 10, which contains frequency distributions, at each dose, of the number of seconds required to complete each of the 55 reinforcements received during the respective experimental sessions. The midpoints of the class intervals (20 sec) of the

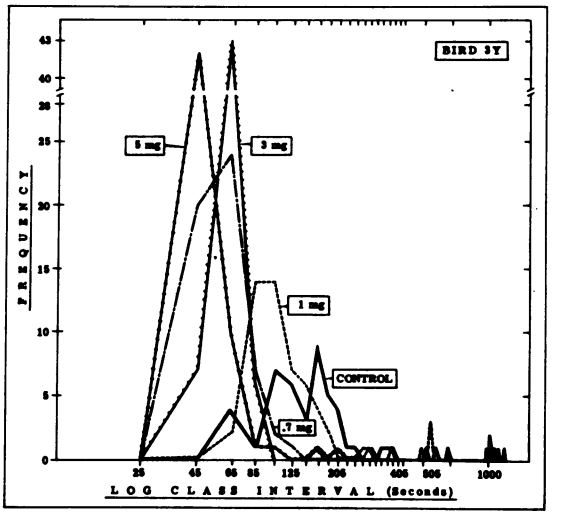

Fig. 10. Bird 3Y. Dose-response curve with pentobarbital giving the entire frequency distribution of inter-reinforcement times for each amount of drug which was administered.

distribution are indicated on a log scale because of the wide range of the measurements from control to experimental sessions. Except for the 7-mg dose, the curves have peaks which shift to the left end of the distribution as the dose is increased. The 7-mg curve reflects the slight upward bend in the dose-response curve of Fig. 9, and indicates a reversal in the direction of the effect of the drug at the higher doses.

With Bird 3Y, injections of chlorpromazine produced some of the rate increases evident in Fig. 9 with pentobarbital and amobarbital; but the performances recorded with chlorpromazine differed in several important details. Figure 11 shows that at doses larger than 2 mg, periods of no effect were intermixed with periods when the rate of responding was

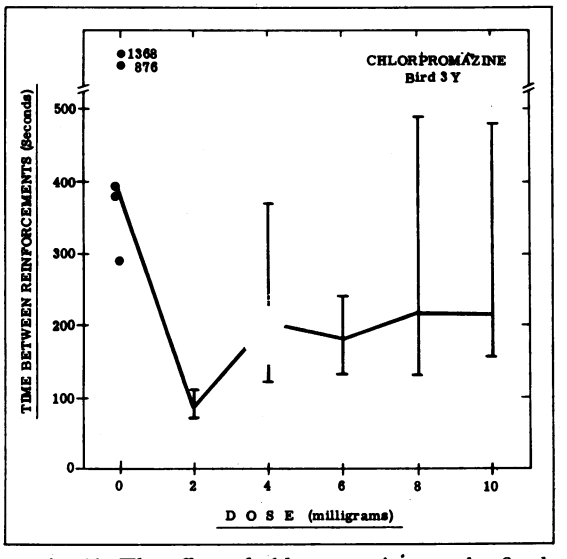

Fig. 11. The effect of chlorpromazine on the fixed-ratio performance. The conditions of the experiment are the same as those described in the legend of Fig. 9.

normal. An example in the the large increase in the 75th percentile, which indicates that more and more fixed-ratio segments are being emitted with pausing comparable with control values. The cumulative curves (Fig. 16) show the effect in more detail. However, the lower part of the range shows that many of the fixed ratios continued to be emitted much more rapidly than control values. Additional injections of amobarbital, pentobarbital, and chlorpromazine confirmed the results reported here.

The results with pentobarbital were compared with those for *d*-amphetamine for Bird 4Y. The general result, shown in Fig. 12, is similiar: The responding increased at smaller doses and through the middle range, but fell off at the larger doses. However, the median time between reinforcements did not reach values so low as those with pentobarb-

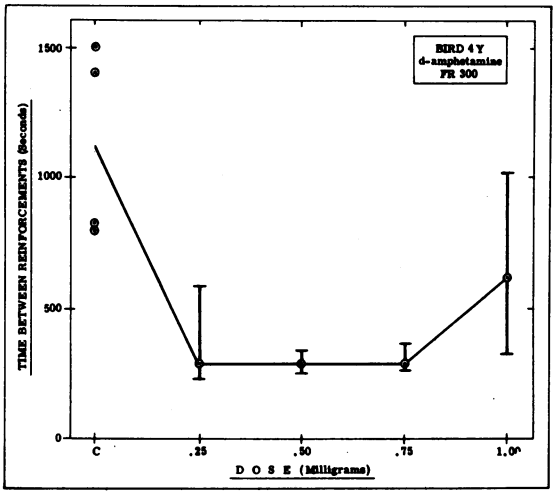

Fig. 12. Bird 4Y. The effect of *d*-amphetamine on the performance at FR 300. The conditions of the experiment are the same as those described in the legend of Fig. 9.

ital, for which the median values varied between approximately 130 and 160 compared with almost 300 sec for *d*-amphetamine injections.

With several injections of pentobarbital, amobarbital, and *d*-amphetamine, the pre–time-out procedure was discontinued for Bird 4Y during the session of the drug administration in order to show the drug effects without the interruptions in the performance during the time outs. The typical results was still obtained. It was also clear in the control experiments described in Experiment I, in which the pre–time-out stimulus procedure was discontinued in an attempt to recover the normal FR performance. The over-all rate of responding increased only after prolonged reinforcement on FR alone. The brief exposure to the FR without the time-out procedure during drug sessions could not have contributed to any rate increases.

Figure 13 shows representative daily sessions at the pentobarbital doses reported in

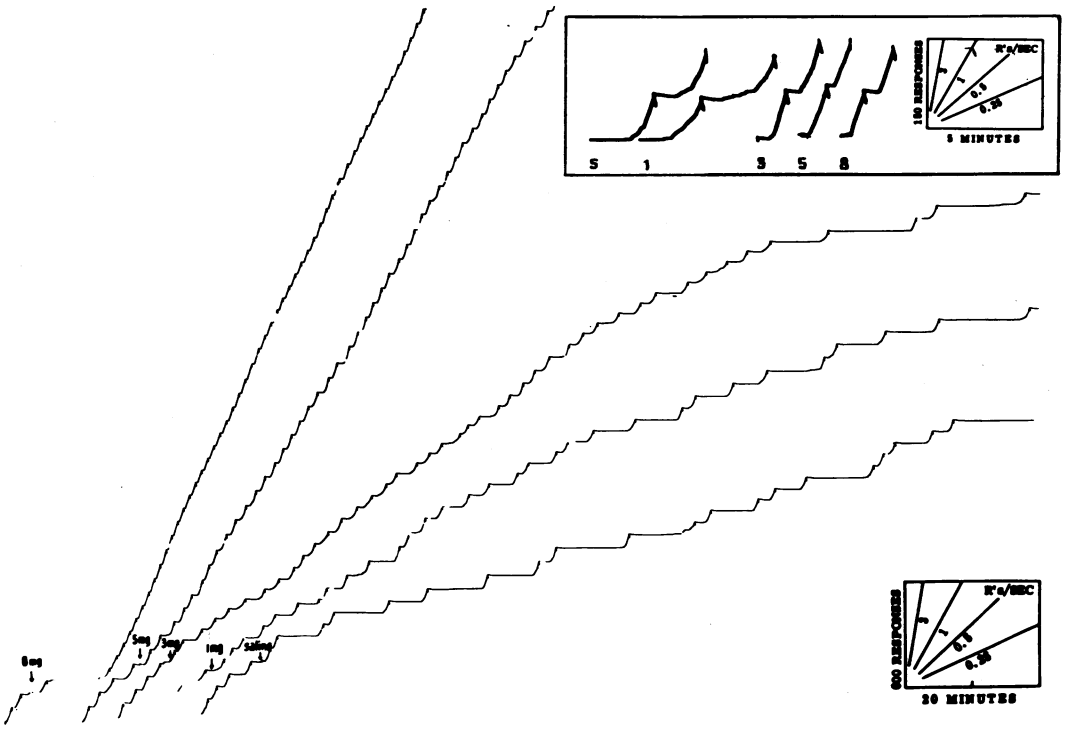

Fig. 13. Bird 3Y. Over-all rate changes during the session with all doses of pentobarbital. The data and the conditions of the experiment have already been presented in the legend of Fig. 9.

the dose-response curve of Fig. 9 for Bird 3Y. The figure shows the over-all rate changes during the session by giving complete sessions in reduced form. The control performance was a low, over-all rate of responding that was roughly constant except for a brief period around the first six reinforcements. After the 1-mg injection, the initial rate of responding was sustained for slightly over an hour before it returned to the base line. After 3 mg, the over-all rate of responding increased further, and was sustained for approximately 100 min. After 5 mg, the over-all rate increased even further, and was sustained to the end of the session, when 55 reinforcements were delivered. A pause occurred only after the 8-mg injection; but the disruption was brief, and the remaining responding in the session occurred at the highest rate yet recorded. The panel in the upper part of the figure shows two enlarged segments from each of the experimental sessions represented in the figure. Besides reducing the pause after reinforcement, the drug injections increased the local rate of responding and changed the form of the curve from curvature to the typical "square pattern" of pause and shift to a terminal rate of responding characteristic of the normal FR schedule.

Figure 14 shows the typical drug effect in more detail for Bird 4Y at a 5-mg dose of pentobarbital. The top part of the figure shows the entire session preceding the drug injection. The arrows indicate pre–time-out stimuli which were followed by time outs; and the numbers above the breaks in the curve indicate pauses, in min, which were deleted from the graphic record. Pausing was extreme, and the over-all rate of responding was very low. The result shown in the bottom part of the figure was a 5-mg injection of pentobarbital at the start of the experimental session. The injection stopped the responding within several minutes, and the first reinforcement did not occur until approximately 40 min later. After another pause of about 10 min, the performance was thereafter sustained until the end of the experimental session, no pause exceeding 2.5 min. The increased rate of responding was caused not only by the reduction in the pause, but also by the substantial increase in the terminal rate of responding in the fixed ratio.

After larger injections of pentobarbital,

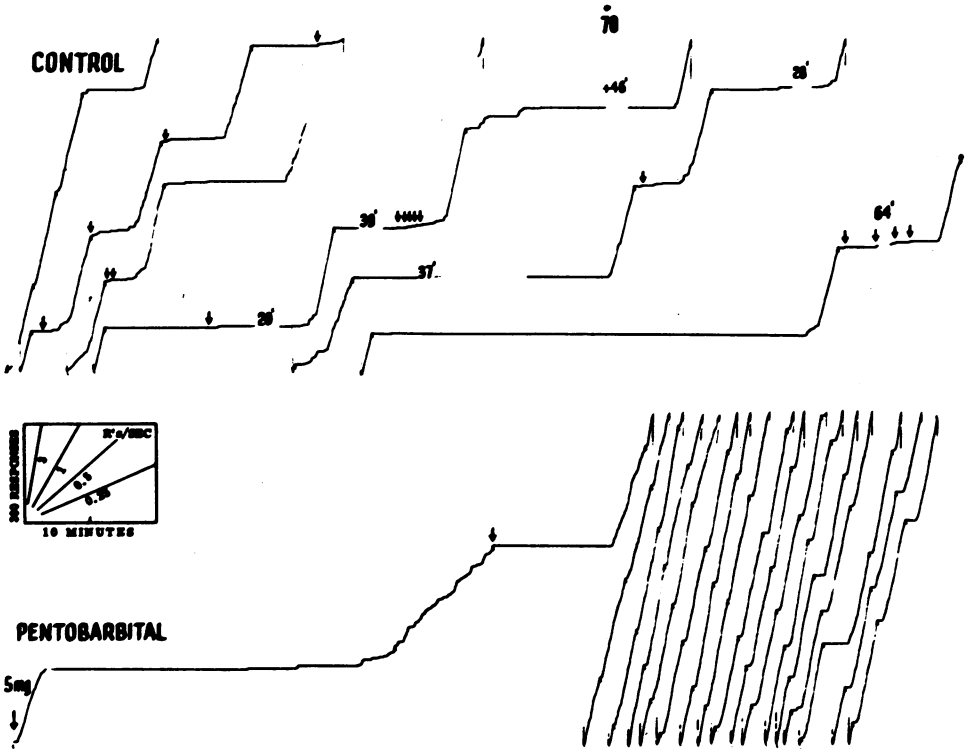

Fig. 14. Detail of effect of pentobarbital for Bird 4Y. The data and the conditions of the experiment have already been presented in the legend of Fig. 9.

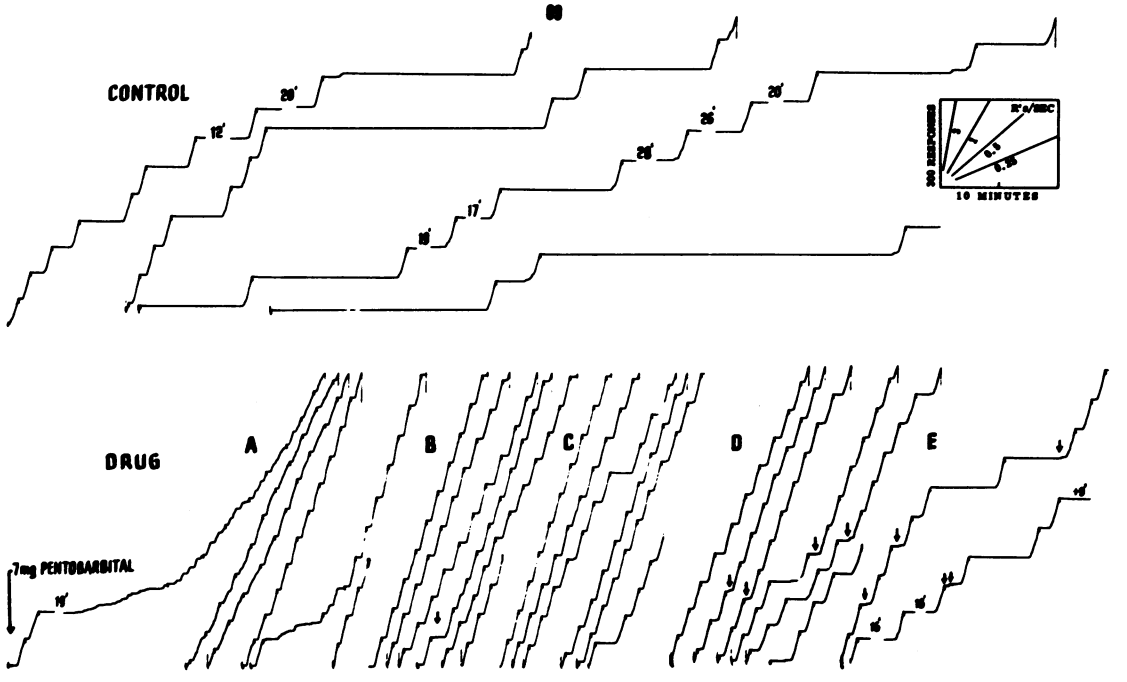

Fig. 15. Illustration of the effect of a large dose of pentobarbital on Bird 3Y, and the continued effect over several sessions. The conditions of the experiment were the same as those described in the legend of Fig. 9.

rates of responding remained high for several sessions, and performances were similar to those just after drug injections. Figure 15 shows the effect on Bird 3Y of a 7-mg injection of pentobarbital. The increased rates persisted for 5 days following the injection. The control performance in the upper curve shows the typical strained, FR performance, with very marked pausing and curvature generally increasing toward the end of the experimental session. At the start of the experimental session in Record A, the 7-mg injection of pentobarbital produced the characteristic effect after some initial pausing. However, in Records B and C, the next two experimental sessions, the rate of responding remained substantial; and only in the final part of Record D, the fourth session following injection, and Record E, the fifth session, did the rate of responding begin to fall to values approaching that of the control session shown in the top part of the figure.

Figure 16 shows two complete experimental sessions illustrating the effect of chlorpromazine in detail. The control session in the top part of the figure shows the normal, strained, control performance. The 6-mg chlorpromazine injection at the start of the session in the bottom part of the figure had an almost immediate effect in reducing the amount of pausing. However, the over-2-hr pause after the 7th reinforcement far exceeded pauses observed during control sessions. Subsequently, the over-all rate of responding remained substantial, although 5- to 30-min pauses still occurred frequently. The results here differed from the effects of pentobarbital largely in the frequent continuation of pausing and curvature intermixed with sustained responding. The terminal rates of responding in the fixed-ratio segments did not increase over control rates, as they did with pentobarbital.

Figure 17 shows a detailed effect of the 0.5-mg injection of *d*-amphetamine, when the base-line performance was very badly strained. As the upper part of the figure shows, only three reinforcements occurred during the entire experimental session preceding the injection. Although a 27-min pause followed this injection, the performance thereafter was

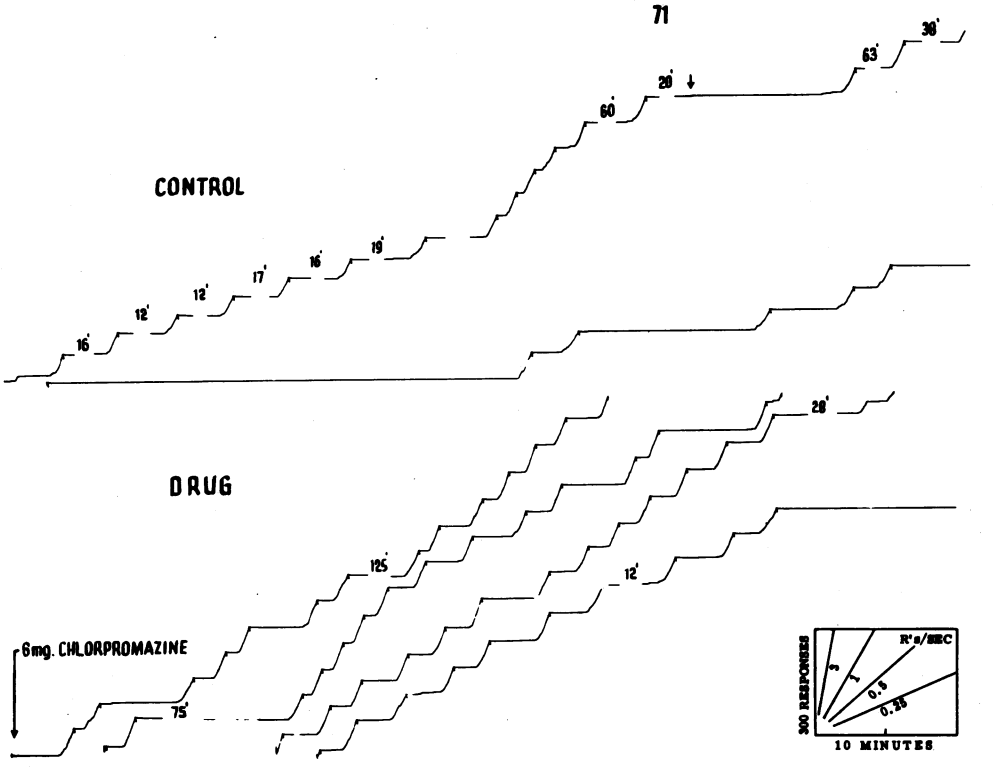

Fig. 16. Bird 3Y. Complete daily sessions showing the effect of 6 mg of chlorpromazine and the preceding control session.

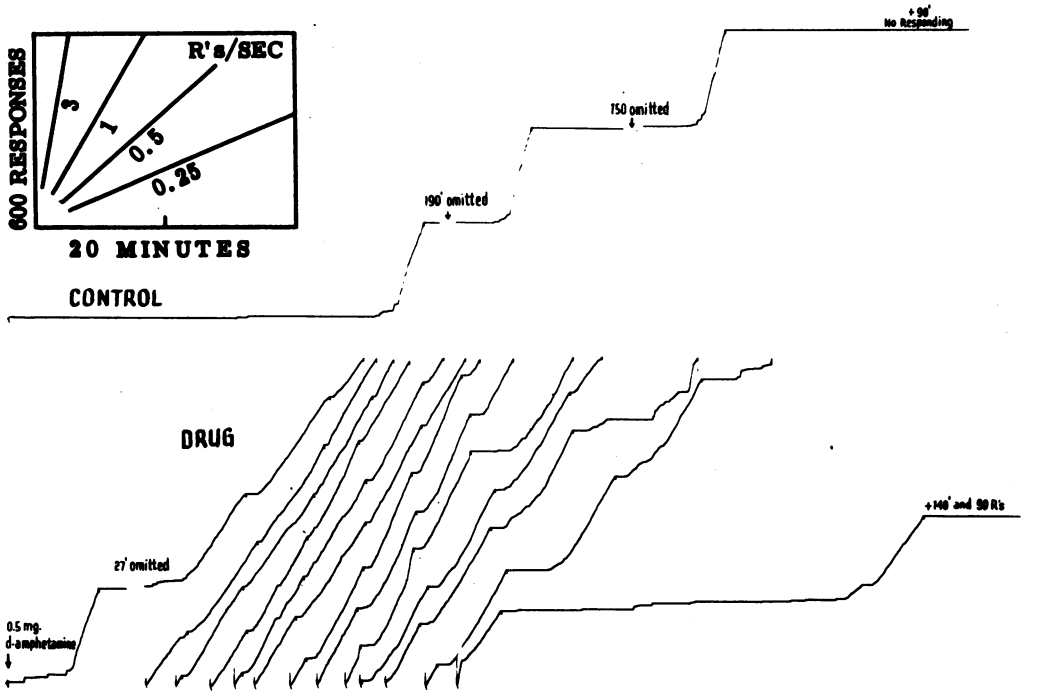

Fig. 17. Bird 4Y. FR 300. The effect of 0.5 mg of *d*-amphetamine. The upper curve is the entire experimental session preceding the injection. The pre–time-out procedures were discontinued during the drug session.

sustained until after 42 reinforcements, when the prolonged pausing again reappeared.[5] The effect of *d*-amphetamine on the local rate of responding was different from that of pentobarbital, amobarbital, or chlorpromazine. Here, the actual terminal running rate of responding in the fixed ratio during the drug sessions was considerably less than the control rates, as other investigators have reported (Morse & Herrnstein, 1956; Kelleher *et al*, 1959a, 1959b; Owen, 1960). The increase in the over-all rate of responding was almost entirely due to reduction in the amount of pausing after reinforcement.

[5]The time-out procedure was discontinued during the session in which the drug was administered.

EXPERIMENT II: DISCUSSION

These experiments confirm the results of previous investigators who have shown increases in rate of responding under fixed-ratio schedules of reinforcement with barbiturates and amphetamines (Ferster & Skinner, 1957; Dews, 1958, Kelleher, *et al*, 1959a, 1959b, 1960; Morse & Herrnstein, 1956). In the experiments reported here, however, the low rate of responding in the FR schedule was produced by a pre–time-out stimulus rather than by the size of the fixed ratio. In addition to increasing the over-all rate responding, the drugs injected in this experiment also altered the very major deviations from a normal FR performance. Desultory responding at the start of the fixed interval, curvature during the early parts of the fixed-ratio segment, and gross variations from segment-to-segment in the terminal rate of responding disappeared whenever the drugs were injected. Dews (1958) has shown that pentobarbital had very little effect on very large fixed ratios (FR 900). The discrepancy between Dews' findings at FR 900 and the other conditions under which pentobarbital does increase rates of responding suggests that the drug is not creating new behavior, but is making it available by altering some of the relevant variables. In our experiment, the increases in over-all rate of responding under drugs may have been due to a disruption of the control of the FR performance by the pre–time-out stimulus, whereas at FR 900 no set of conditions might exist (other than variables such as increased

amounts of reinforcement) that might increase the rate of responding. Similarly, the increases in rate observed with more medium-range FR's may be due to a disruption of the factors which produce pausing in spite of the relatively high frequency of reinforcement, as, for example, the number of responses in the FR as a discriminative stimulus. The effect of a drug injection on a medium-size FR might be analogous to a transition from an FR to a VR with mean value equal to the FR. Performances are sustained under VR at substantially higher over-all rates than those occurring on the FR, probably because the number of responses emitted between reinforcements does not control the organism's behavior.

We have confirmed the main findings of this experiment using a fixed-ratio schedule without a pre–time-out stimulus. The increases in rate of responding recorded on a simple FR schedule under the same conditions and with the same doses of drug as in this experiment suggest that the drug effects reported here do not depend upon the pre–time-out procedure. Rather, the pre–time-out procedure probably represents a procedure which produces grosser disturbances from a normal FR pattern which can then be "normalized" by the drug injections.

Increases in rates of responding under the pre–time-out stimulus procedure occurred at doses considerably higher than those reported with pentobarbital in other base lines in previous experiments except for the effects of chlorpromazine on observing responses (Kelleher *et al*, 1960). Typically, the range of doses producing increased rates of responding on fixed-interval performances is 0.5-2.0 mg with the pigeon. Some increases in rate of responding on interval schedules have been reported after recovery from large doses (Verhave, 1959); however, the number of observations is small, and our experience in this laboratory has been that such effects tend to be transitory. The increased rates over a wide dose range under the FR schedule suppressed by the time-out procedure may be due to the relatively favorable frequency of reinforcement in terms of responses per reinforcement. The drug might act by giving the bird behavior it has potentially available by disrupting the control by the pre–time-out stimulus. The rates of responding potentially available are those normally produced by the FR schedule undisturbed by the time-out procedure.

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