TIME LIMITS FOR COMPLETING FIXED RATIOS[1]

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Two experiments investigated how the addition of time limits affected fixed-ratio behavior. In Exp. 1, pigeons obtained food only if they completed the ratio within a specified time after the end of the preceding ratio. In Exp. 2, they obtained food only if they took longer than a specified time. Failures to meet the time criteria produced brief timeouts. The times taken depended on the requirements in both experiments. In Exp. 1, progressively briefer time criteria resulted in faster ratios, and in Exp. 2, longer time criteria increased the time taken in each ratio. The pigeon's sensitivity to the temporal variable, a property of the entire period extending from the first opportunity to respond to the end of the ratio, indicated that performance involved a behavioral unit encompassing both the post-reinforcement pause and the responses comprising the ratio.

Animals emit an orderly sequence of behavior when food appears after a fixed number of responses. Subsequent research on these fixed-ratio (FR) schedules has confirmed Skinner's (1938) report that animals either respond at a stable, substantial rate or pause after food delivery and then respond rapidly until the next food presentation. This high degree of uniformity lends itself to the interpretation that the entire sequence of behavior has a unitary character (cf., Lashley, 1951).

Skinner (1938) first proposed a unitary view of fixed-ratio performance by suggesting that all of the responses in ratios may function as single units. Mowrer and Jones (1945) reasoned from this that a constant number of ratios might be emitted when reinforcement was discontinued. However, they and others (Boren, 1961; Weissman and Crossman, 1966) were unable to account for resistance to extinction with such an analysis. A possible reason for the lack of success is that extinction may not reveal directly the nature of behavior that was established by prior reinforcement. Nonreinforcement does not just passively reveal the properties of established behavior, but instead first intensifies and then weakens

responding (cf., Amsel, 1967; Morse, 1966). These active effects could well preclude precise quantitative relations between ratio units and resistance to extinction. On the other hand, data involving maintained reinforcement favor some form of unitary response analysis. Ferster and Skinner (1957) reported that two fixed ratios considerably different in size, with no exteroceptive stimulus to indicate which was in effect, revealed sensitivity to the amount of behavior emitted. Others (e.g., Pliskoff and Goldiamond, 1966; Rilling and McDiarmid, 1965) also showed that pigeons differentiated the number of responses emitted on two fixed-ratio schedules. The birds' behavior had to depend on some characteristic of total ratios because no single response differentiated long from short schedules. The nature of the differentiating property, however, has not been explained.

In addition to the possibility that behavior in extinction is an inappropriate test, Skinner's and Mowrer and Jones' conceptualization of the unit as being the responses comprising the ratio itself might be incorrect. If there are integrated units, there is no a priori reason to exclude the post-reinforcement pause and to consider only the responses that meet the ratio requirement. In fact, some data imply that pauses should be considered. When Findley (1962) and Kelleher, Fry, and Cook (1964) studied fixed ratios in which food presentations depended on a minimum post-reinforcement pause, pause durations changed accord-

ingly. Animals received food at the completion of a ratio only if the post-reinforcement pause exceeded a specified duration. Otherwise, completion of the ratio produced only a change in key color. Evidently, the reinforcing stimulus acted back over the entire subsequent run of responses to control pausing. If food presentation reinforces both meeting the ratio requirement and prior pausing, perhaps both components become integrated and function as a unit.

The fundamental problem is that of fruitful levels of analysis of an operant. The pigeon's pecking of a response key illustrates some conceptual and methodological issues generated by such analyses. Response-key operation has a number of attributes; for example, it is a term representing the topography, minimal duration, and minimal force of some event. It is an operant in any situation in which the probability of key pecking varies depending on its consequences. Identification of the functional properties of the operant requires more than the demonstration that an aspect of behavior is related to an experimental manipulation. To be a functional dimension, the probability of the property itself occurring must be controlled by its effect on the environment. For example, if certain forces or durations are imposed as requirements for reinforcement, the probability of the subject emitting a peck of the required force or duration should vary accordingly. Differential responding with respect to a property illustrates the functional reality of that property, and, to the extent that the property belongs only to a certain operant, it testifies to the experimental significance of that operant. Thus, the analysis of whether a class of events is profitably considered an operant requires isolating a defining property and showing that its probability varies lawfully depending on its consequences.

Investigation of unitary characteristics of behavioral sequences therefore requires specifying unique properties of the hypothesized unit. The time elapsing between the first opportunity to respond and the completion of a fixed ratio qualifies in this respect. The total time taken to begin and complete a ratio—the post-reinforcement pause plus the time taken to emit all of the responses—belongs not to any single response but is the duration of the entire sequence. Hence, if specific total times are criteria for food presentation and behavior changes accordingly, the performance would appear to involve response units encompassing all of the behavior occurring between successive reinforcements. Neuringer and Schneider's (1968) demonstration that interreinforcement time does play an important role in ratio behavior supports this hypothesis. The present research modified the procedures reported by Findley (1962) and Kelleher *et al.* (1964) to investigate whether the time taken by pigeons to complete each ratio (pausing time plus pecking time) varied as a unitary aspect of behavior.

EXPERIMENT 1: FIXED RATIOS COMPLETED IN LESS THAN A SPECIFIED TIME

If pigeons completed a ratio in less than the time specified, they received food. If not, the color of the response key changed briefly and the ratio began anew. The time taken to complete ratios was recorded as a function of the specified time criteria.

METHOD

Subjects

Four White Carneaux pigeons were maintained at 80% of their free-feeding weights. Birds 54 and 56 had not served in other experiments; Birds 2 and 55 had prior training in simultaneous discriminations involving differential reinforcement under variable-interval or fixed-ratio schedules.

Apparatus

The experimental chamber was a standard single-key unit (Ferster and Skinner, 1957). The 1 in. (2.5 cm) diameter response key (R. Gerbrands Co.), operated by a minimum force of 12 g (0.12 N) was transilluminated by either red or green 7-w lamps. A 2 in. (5 cm) square aperture centered 3 in. (8 cm) below the key provided occasional access to mixed grain. During the 4-sec feeder cycles, a 7-w white lamp illuminated the aperture, and the keylights went off. A houselight provided dim general illumination, and continuously present white noise masked extraneous sounds.

Procedure

The experiment consisted of four phases that studied three different procedures. The

Table 1
Sequence of Conditions and Time Criteria: Exp. 1

	Bird 54		Bird 55		Bird 56		Bird 2	
Phase	FR	Time in Sec.	FR	Time in Sec.	FR	Time in Sec.	FR	Time in Sec.
1. TO on time	FR 15	Infinite, 60, 30, 15, 10, 15, 10, 8, 10, 8, 6, 8, 10	FR 30	Infinite, 60, 30, 15, 30, 15, 10, 15	FR 15	Infinite, 60, 30, 15, 10, 6, 10, 6, 4, 6	None	
2. TO on ratio	FR 15	Infinite, 30, 20, 15, 12, 10, 8, 10, 8, 10, 12, 60	FR 30	Infinite, 60, 30, 20, 15, 20, 60	FR 15	Infinite, 15, 10, 15, 10, 8, 6, 4, 6	None	
					FR 30	Infinite, 60, 30, 20, 15, 20		
3. TO on ratio with Black-out	FR 15 FR 30	Infinite Infinite, 60, 30, 20, 15, 12, 10	FR 30	Infinite, 60, 30, 20, 15, 12, 10, 12, 10	FR 30	Infinite, 60, 30, 20, 15, 12, 15, 12, 10	FR 30	Infinite, 60, 30, 20, 15, 12, 10, 8, 10, 8, 6, 4, 6
4. TO on ratio	None		None		None		FR 30	8

three procedures provided systematic replications of how maximum times permitted to complete ratios influenced the time taken, and thereby explored the generality of the functional relations obtained. Birds 54, 55, and 56 participated in Phases 1, 2, and 3, and Bird 2 served in Phases 3 and 4. Table 1 summarizes the procedures.

Phase 1: timeout on time. A green light transilluminated the key while Birds 54 and 56 were shaped to peck the key. Bird 55 needed no shaping because of its prior experience. At first, every key-peck produced food, then the schedule was raised gradually to FR 15 for Birds 54 and 56 and to FR 30 for Bird 55. These schedules continued for 30 sessions.

Maximum time criteria then were imposed. The birds received food whenever they took less than the time specified to complete a ratio. The critical time began with the first opportunity to respond; thus, to obtain food the time spent in pausing and responding had to total less than the criterion. Longer times resulted in a timeout, during which the key color changed from green to red and responses had no scheduled effect. In Phase 1, a 15-sec timeout began as soon as the birds exceeded the allotted time ("TO on time"), and ratios began anew after each timeout.

The criteria were selected from the following: infinite (no criterion), 60, 30, 15, 12, 10, 8, 6, and 4-sec. After behavior stabilized with the infinite criterion, the time was shortened

progressively until there was a maintained sharp decrease in response rate. Occasionally, the descending sequence of times was reversed to assess the recoverability of behavior. Each criterion continued for at least eight sessions and until the overall rates of responding for each of three successive sessions were within 5% of the median day of the three.

Phase 2: timeout on fixed ratio. In Phase 2, the timeout occurred at the end of the fixed ratio ("TO on ratio"). Whereas in Phase 1, timeouts began as soon as the allotted time elapsed and therefore could occur at any point in the ratio, in the second phase they occurred only when the ratio was completed. Phase 2 revealed whether the behavior of Phase 1 depended on the particular procedure used to introduce timeouts.

Timeouts were shortened to 4-sec to match the duration of feeder cycles. After a number of sessions with no criterion, a range of times was imposed in a descending order interrupted by occasional reversals. Each criterion continued until behavior stabilized. The descending order stopped with the criterion that sharply decreased the response rate. Bird 56 was studied first under FR 15 and then under FR 30; the other birds continued with the same ratio as in Phase 1.

Phase 3: timeout on fixed ratio with blackouts after every ratio. Phase 3 used a new procedure to provide a third parametric study of time criteria. As in Phase 2, timeouts occurred

at the end of the ratio. However, a 1-min blackout with house and keylights off followed each food presentation and timeout ("TO on ratio with blackout"). This procedure investigated how time criteria affected behavior when the opportunity to complete a ratio did not immediately follow the food presentation or timeout delivered dependent on the behavior of the preceding ratio. Responses during the blackout had no scheduled consequences.

Bird 2 began the experiment with this phase to provide data with blackouts without a prior history with ratios involving time criteria. For Bird 2, the schedule was raised from FR 1 to FR 30 within two sessions and was maintained at that value.

As in the other phases, the first criterion was infinity and then the time permitted was reduced until the response rate decreased. For Birds 2, 55, and 56, each criterion continued until behavior stabilized. Bird 54 never stabilized. After 30 sessions at FR 15 with no criterion, the schedule was changed to FR 30 first without and then with criteria. Criteria were maintained for 20 to 30 sessions each. Under all conditions, sessions of responding at a high rate alternated unpredictably with sessions having too few responses to obtain 30 food presentations in a 2-hr period. Birds 55 and 56 had an FR 30 schedule throughout the phase.

Phase 4: timeout on fixed ratio. Only Bird 2 participated in Phase 4. This bird was switched from the blackout procedure of Phase 3 to an 8-sec criterion with no blackouts. Timeouts and food presentations occurred at the end of the ratio, but as in Phase 2, ratios were not separated by blackouts. This condition studied how a short criterion with ratios uninterrupted by blackouts affected a bird that had experienced only ratios followed by blackouts.

Sessions lasted for 50 food presentations in Phase 1 and then were shortened first to 40 and then to 30 to limit the weight gain in each session and to shorten the sessions. Sessions occurred daily except for weekends and occasional holidays.

RESULTS AND DISCUSSION

Behavior as a Function of Time Criteria

The most direct measure of the effects of the time criteria would be the time elapsing

during individual ratios. However, this was unsuitable for the "TO on time" procedure of Phase 1, because the criterion established a ceiling and ratios were not always completed. Timeouts could occur before the first response or at any other point in the ratio. Response rate, therefore, describes the results of that phase in Fig. 1. Rate was computed by dividing the total responses in the session by the total time exclusive of food magazine and timeout cycles. In Phases 2, 3, and 4 elapsed time during each ratio was the appropriate dependent variable, since every ratio was completed. The average time to complete each ratio was computed by dividing the total session time, exclusive of magazine, timeout, and blackout cycles, by the number of ratios completed. These data appear in Fig. 2. Figures 1 and 2 show the stable response rates and ratio times respectively for the last session in the first exposure to each criterion. (Phase 3 for Bird 54 is excluded because of the instability.) To minimize warm-up effects, time and responses were measured starting with the ratio following the first food presentation. Stable behavior required no more than 32 sessions, with the number varying unsystematically for Birds 2, 54, and 55, and never exceeding 14 for Bird 56.

The effects of the time criteria were independent of procedural variations. As the time criteria decreased, reading from right to left on the abscissa, the response rates in Fig. 1 and
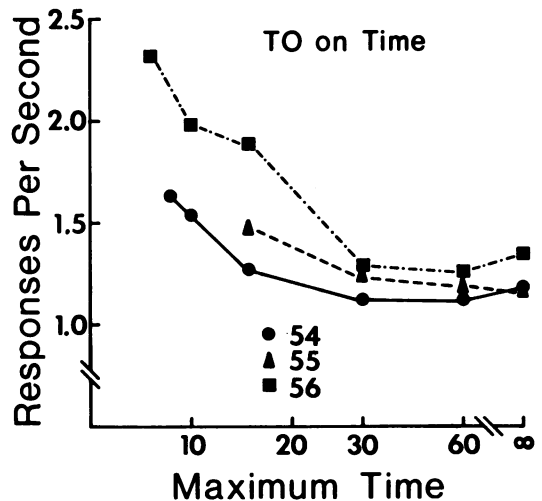

Fig. 1. Rate of responding when timeouts occurred as soon as the allotted time was exceeded. The abscissa is on a logarithmic scale.

ratio times in Fig. 2 first did not change systematically. Behavior did not come into contact with the longer criteria: at 60-sec, and sometimes at 30-sec and 20-sec, the baseline rate attained with no criterion was high enough to meet the requirements. From 15 to 50 timeouts occurred in the first two or three sessions with shorter criteria. Those criteria, which did contact behavior, increased rates and decreased ratio times. The increase in probability of the required behavior is evident in that, excluding the warm-up period, no bird had more than six timeouts during the final three sessions with any criterion. Temporary reversals of the descending sequence of criteria reproduced the slower rates

and ratio times observed initially. Thus, the orderly changes depicted in Fig. 1 and 2 depended on the time criteria and not on long-term effects of the ratio itself. Since the redetermined points were almost identical to the originals, they are not shown in the figures.

Cumulative records revealed that each criterion established either pausing followed by a stable response rate or a high steady rate without a preceding pause. Response rates and the times taken to complete individual ratios were similar whether ratios ended with a food presentation or with a timeout. With the exception of the warm-up period, timeouts followed ratio times that only slightly exceeded the criterion.
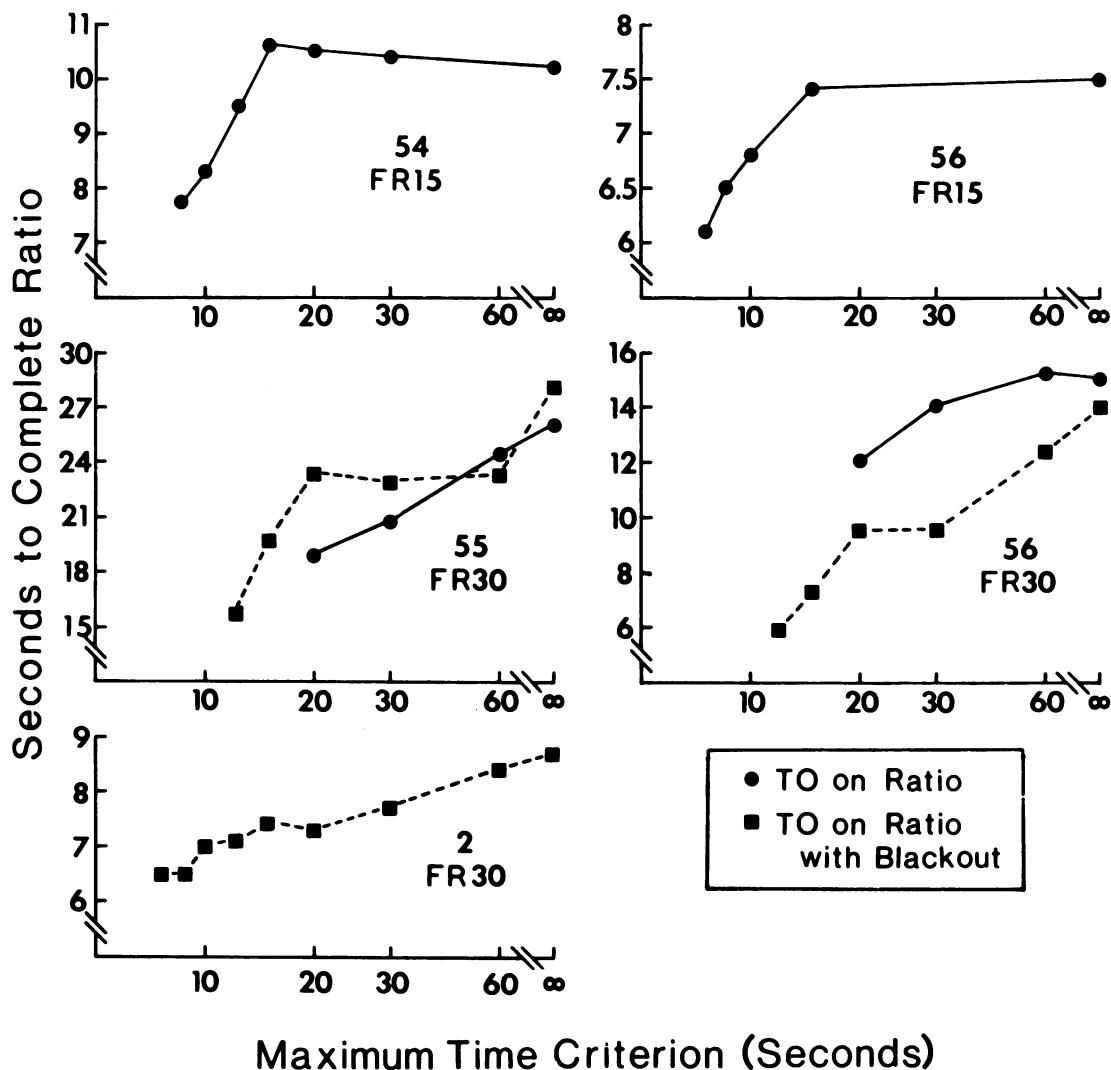

Fig. 2. Average time to complete ratios.

Post-reinforcement Pauses and Post-pause Responding

The effect on overall response rate and ratio time could have been due to changes in either the duration of the initial pause (pause time) or in the rate of responding after the pause (running rate). To assess the locus of the effect, pause time and running rate were recorded separately beginning with the "TO on ratio" phase. These data were recorded only for ratios following food presentations on the assumption that post-reinforcement and post-timeout behavior might be too different to be combined. However, cumulative records later suggested that this assumption was unwarranted. Figure 3 shows the data for the last session with each criterion. Total pause time and total post-pause time were cumulated over all of the post-reinforcement ratios of the session. The pause data are the total pause times divided by the number of post-reinforcement ratios. The running rates are the total responses in those ratios divided by the post-pause times.

The summary data were representative of behavior in individual ratios. Since multiple pauses were rare and the birds usually shifted from pausing to responding at a steady rate, the average running rate corresponded well with the momentary rates occurring during the period of responding. For Birds 2, 54, and 56, both pause time and running rate changed to meet the criteria, in that pause time decreased and running rate increased with progressively shorter time criteria. For Bird 55, pause time decreased with progressive changes in the criteria, and running rate was constant until it increased with the 20-sec criterion in the "TO on ratio" phase and at 12-sec in the "TO on ratio with blackout" phase. These data, taken together, show that the criteria influenced both the post-reinforcement pause and the running rate, but that the precise interplay of the two aspects of behavior varied between birds.

Behavior under the Shortest Criteria

The functions reported above changed so markedly with the lowest criterion that it is necessary to present these results separately. The shortest criteria produced a 1.5- to 4-fold decrease in overall response rate. (For Bird 54,

the second exposure to 8-sec in the "TO on FR" phase produced the decline.) The number of timeouts increased, the average rate decreased, ratio time increased, and pause time increased. In Phases 1, 2, and 4, the phases in which blackouts did not separate successive ratios, timeouts regularly alternated with food presentations. No summary statistic could represent all ratios, as there were two distinct forms of behavior. After a timeout, there was a high response rate and no preceding pause. The birds responded through the timeout and continued until the next ratio was completed and food was presented. After a food presentation, there was a pause followed by erratic responding in the "TO on ratio" phase, and almost no responding in the "TO on time" phase.
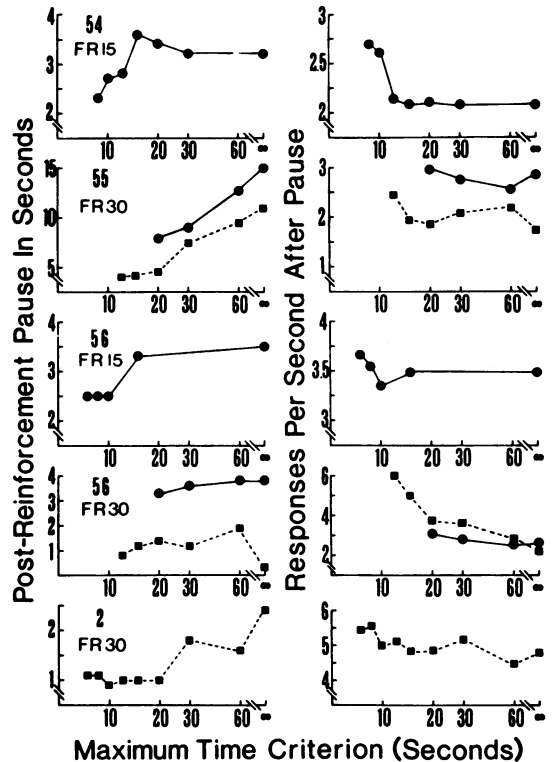

Fig. 3. Pause time and post-pause running rate. Circles are for the "TO on ratio" phase, and squares are for the "TO on ratio with blackout" phase.

Figure 4 shows two sessions with Bird 55 that illustrate the alternating pattern and also show the effect of switching from the shortest to an infinite criterion. Pauses after food presentations lasted up to 70-sec, and there were
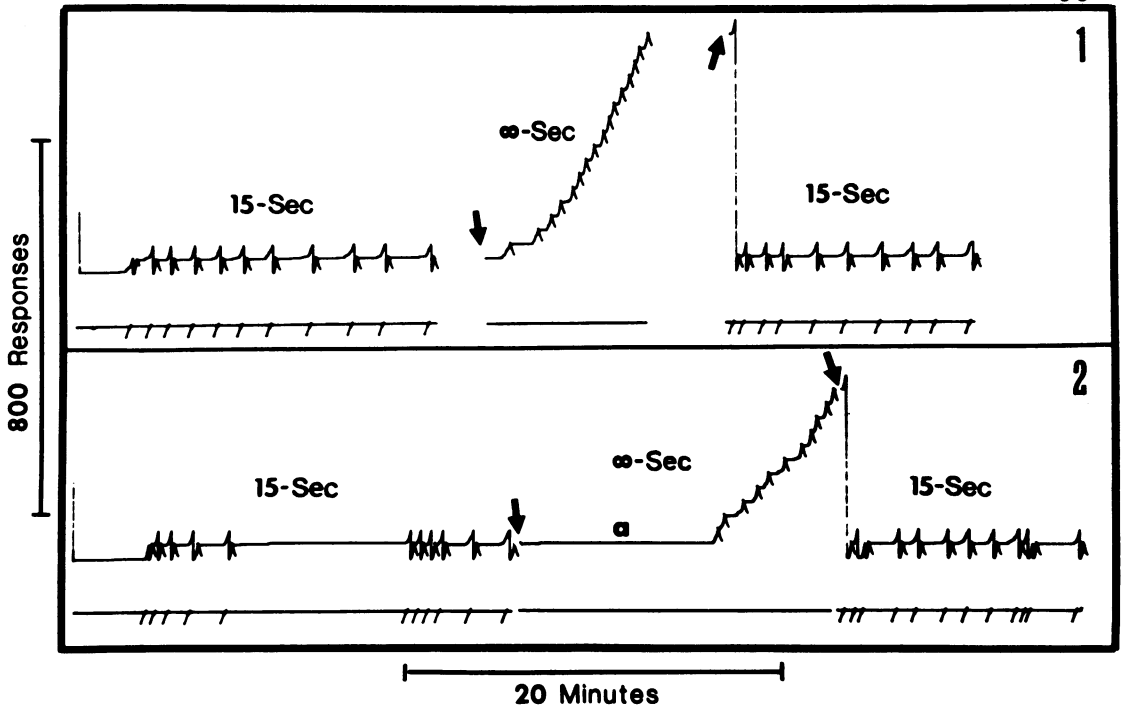
Fig. 4. Cumulative records for two sessions involving criterion changes from the shortest to the longest value. Arrows show the points of the changes. Displacements of the response marker show food presentations. Displacements of the event pen and resets of the response marker indicate timeouts.

also some pauses after responding began. Timeouts were followed by high response rates without pauses. With the change from 15-sec to an infinity criterion, the first ratio revealed long pauses (over 600-sec in the second session at "a"), but with continued exposure, pauses decreased and running rate stabilized. The first timeout with the return to 15-sec reinstated the alternating pattern. Therefore, whether food presentations generated long or short pauses depended on whether they were followed by additional presentations or by timeouts. The behavior may have resulted from an inevitable post-reinforcement pause. When the criterion was so short that any pause precluded food presentation, the bird could not obtain food in two successive ratios. Food could become a negative discriminative stimulus controlling longer than average pauses and erratic response rates, while timeouts generated a high rate that continued until food appeared.

The pausing and erratic rates controlled by food presentations in Phase 2 were not eliminated readily. Birds 54 and 55 continued to

alternate timeouts and food presentations under the 60-sec criterion. Only Bird 56 lost the alternation when changed from the shortest to the next longer criterion. Eventually, all of the birds resumed the earlier behavior of a high steady rate usually preceded by a post-reinforcement pause.

The preceding description does not fit Phase 3 when blackouts followed each food presentation and timeout. Blackouts produced the shortest ratio times and pauses and the highest running rates of the experiment. Increased ratio times and pauses at the shortest criteria occurred because high rates were followed by low rates or by pauses lasting up to 15-min. These pauses occurred during the completion of the ratio as well as before the first response and were unrelated to whether the preceding ratio ended in a food presentation or in a timeout. Bird 2 demonstrated that these effects did not depend on a history with fixed ratios having time criteria. Blackouts apparently prevented the development of stimulus control by food and timeout cycles. Bird 2 did alternate food and timeouts in Phase 4.

EXPERIMENT 2: FIXED RATIOS COMPLETED IN MORE THAN A SPECIFIED TIME

Experiment 1 demonstrated that the time taken to complete a fixed ratio progressively decreased as pigeons were permitted increasingly shorter times. Experiment 2 investigated the effects of having food presentation depend on the completion of a ratio in longer than a specified time.

METHOD

Procedure

The subjects and apparatus were the same as in Exp. 1. Experiment 2 began immediately after Exp. 1 ended. The procedure was that of Phase 2 of Exp. 1, except that the time requirements involved minimum rather than maximum time criteria. Both timeouts and food presentations occurred at the completion of the ratio. Food presentation followed ratios completed in longer than the time specified since the preceding food presentation or timeout, and a 4-sec key color change from green to red followed ratios completed in shorter times. There were no blackouts.

Table 2 shows the sequence of procedures. Bird 2 received FR 60 and time criteria of the following durations: 0 (no criterion), 10, 20, 30, 40, and 60-sec. Birds 54 and 56 had FR 30 and time criteria selected from the following values: 0, 8, 10, 12, 16, 20, and 30-sec. Bird 55 had FR 15 with the following criteria: 0, 4, 6, 10, 16, and 20-sec. The criteria were imposed first in an ascending and then in a descending order. After the descending sequence, each bird was shifted directly from the 0-sec criterion to the longest value and then back to 0-sec. As in Exp. 1, a given criterion continued for at least eight sessions and until the median response rate for three successive days was within 5% of the rates for each of the three

days. All sessions lasted for 30 food presentations.

RESULTS AND DISCUSSION

Behavior as a Function of Time Criteria

Figure 5 shows the mean ratio time (total session time, excluding magazine and timeout cycles, divided by the number of ratios completed) for the last session with each criterion. Again, warm-up effects were excluded by beginning to record time with the ratio after the first food presentation. Since the criteria specified the minimum time that the bird had to take to obtain food, longer times indicated more stringent requirements. With the shortest times, there were no timeouts and little behavioral effect, but, as the time criteria increased further, ratio times also increased. In fact, ratio times often closely corresponded with required times. This function, increased ratio time with increased required time, was replicated with both ascending (circles) and descending (squares) sequences of changes in the criteria. (Triangles are in both categories as they represent changes from 0-sec to 60-sec and back to 0-sec. They also replicated the general function.) Failures to meet the criteria occurred because the behavior fell slightly short of the requirement; thus, there were no marked differences when behavior did or did not conform.

Although the shape of the function was replicated, no bird recovered the same absolute ratio times at every criterion. Bird 54 did not deviate systematically from the initial values. Bird 56 recovered the original behavior with 16-sec and 20-sec, but responded more slowly with the second exposure to 10-sec. Birds 2 and 55 differed most consistently between replications, both responding more slowly with the second exposure to all of the criteria. If longer times were maintained because they were followed by food presentation,

Table 2

Sequence of Time Criteria: Exp. 2

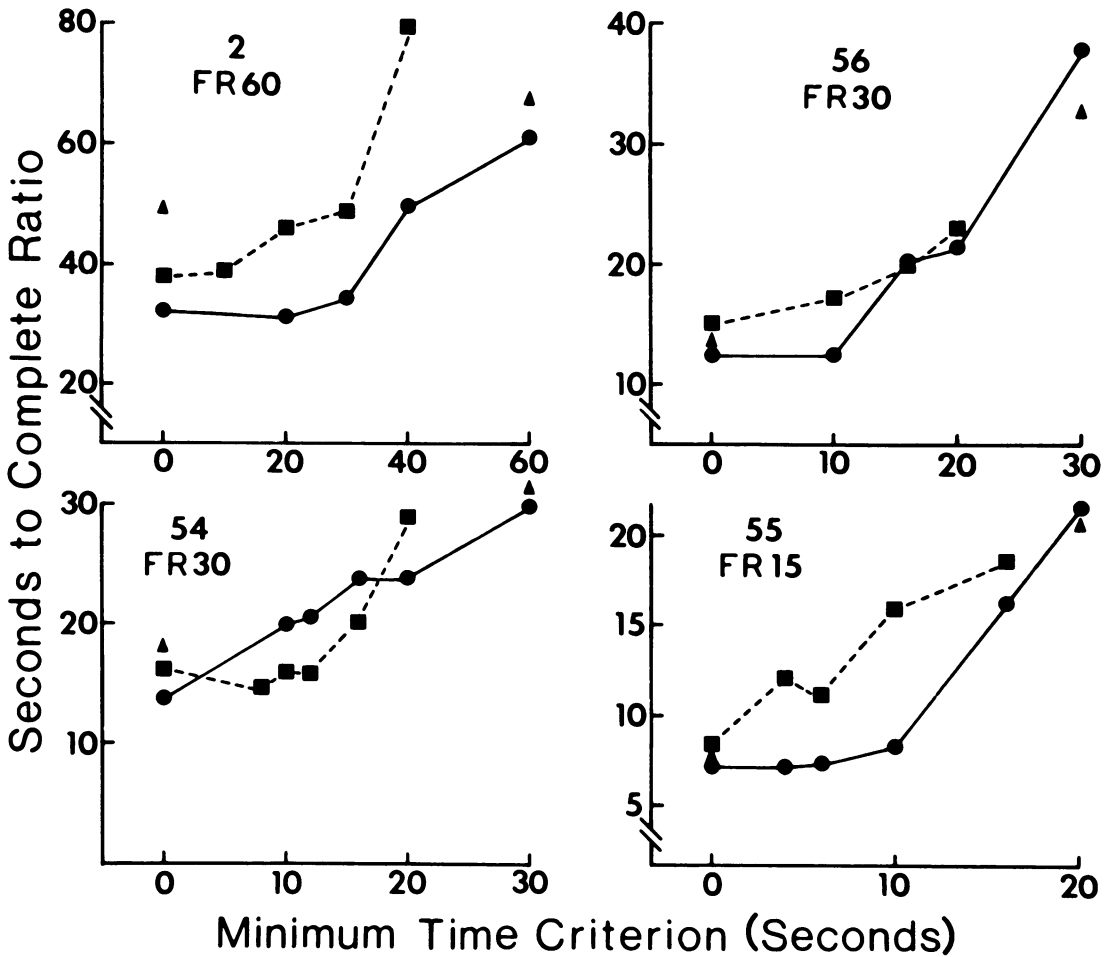|	Bird 2		Bird 54		Bird 55		Bird 56
FR 60	0, 20, 30, 40, 60, 40, 30, 20, 10, 0, 60, 0	FR 30	0, 10, 12, 16, 20, 30, 20, 16, 12, 10, 8, 0, 30, 0	FR 15	0, 4, 6, 10, 16, 20, 16, 10, 6, 4, 0, 20, 0	FR 30	0, 10, 16, 20, 30, 20, 16, 10, 0, 30, 0

Fig. 5. Average time to complete ratios. Circles are for the initial ascending sequence of criteria, squares are for the descending sequence, and triangles are for the last exposures to the extreme values.

this is an example of behavior persisting due to adventitious effects of reinforcement. Perhaps the times eventually decreased because some variability resulted in a shorter ratio time that was followed by food and thereby became more probable.

Post-reinforcement Pauses and Post-pause Responding

With all of the criteria Bird 54 had stable running rates throughout each ratio. However, this did not occur with the longer criteria with the other birds. Figure 6 shows that Birds 55, 56, and 2 revealed positively accelerated responding after the pause in some ratios under the longest criteria, and Bird 2 had ratios in which there was positive followed by negative acceleration. Herrnstein and Morse (1958) also found that stable running rates did not always

appear when minimum interreinforcement times were controlled.

Figure 7 shows the mean post-reinforcement pause and the mean rate of responding after the pause in the last session with each criterion. (See Exp. 1 for a description of the data analysis.) To conform with Exp. 1, data were recorded only after ratios ending with food presentations. In general, pausing increased as the criterion increased. Running rate is more difficult to evaluate because of the positively and negatively accelerated rates of responding that occurred with the longer criteria. However, Birds 2, 55, and 56 did decline in average running rate whenever ratio time increased. In contrast, Bird 54 revealed no orderly relation of running rate to the criteria. Instead, running rate was positively correlated with the number of timeouts (rank order cor-
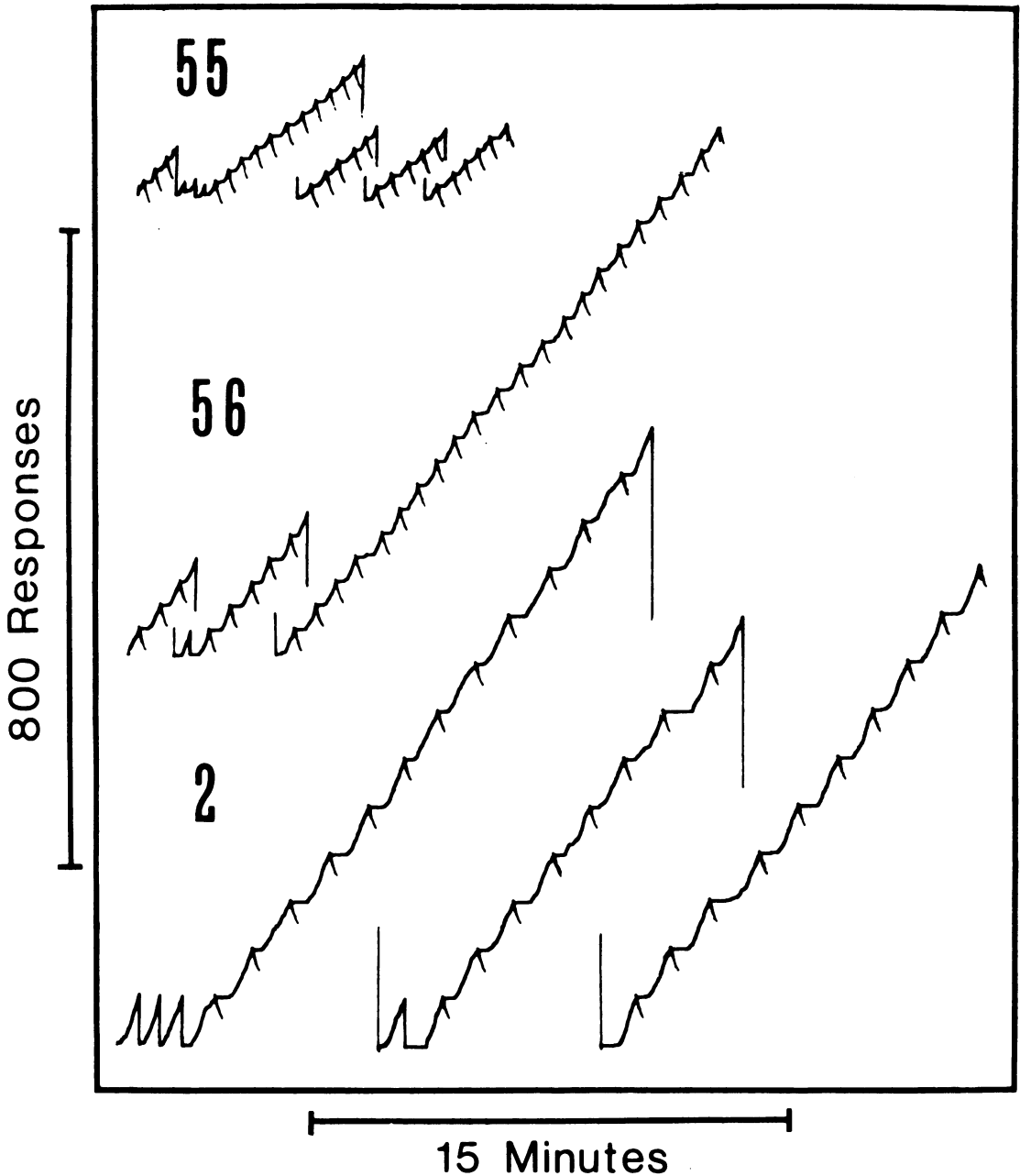
Fig. 6. Cumulative records for the longest criteria with Birds 55, 56, and 2. Displacements of the response marker show food presentations. Resets of the response marker indicate timeouts.

relation of +0.88 based on the median session of the last three at each criterion). This correlation may have reflected a continuing effect of Exp. 1 when increased rates decreased the frequency of timeouts.

GENERAL DISCUSSION

The two experiments revealed that the time taken to complete a fixed ratio varied widely

(*e.g.,* from less than 6-sec to nearly 40-sec for Bird 56 with an FR 30 schedule) according to whether maximum or minimum times were required for food presentation. Since Exp. 2 demanded continually longer times and Exp. 1 demanded shorter times, and since the consequences of conforming and not conforming to the requirements were identical in both experiments, changes in ratio time must be at-
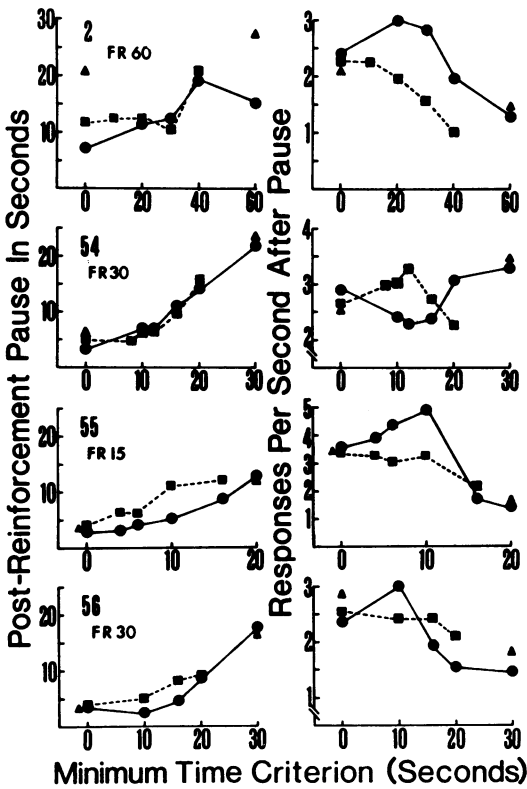
Fig. 7. Pause time and post-pause running rate. Symbols are as in Fig. 5.

tributed to specific time criteria and not to general effects of continued exposure to fixed ratios, or to timeouts, or to other shared procedures.

These experiments support the conception of a response unit based on an integration of pauses and subsequent responses. The most orderly dependent variable was the time elapsing during each ratio, that is, the behavior of consequence in determining whether food or a timeout followed the ratio. Pausing and running rate often changed together and sometimes did not; what is most significant is that the total time taken was always a function of the time required. Unitary properties changed systematically, while more molecular aspects of behavior did not have an equally orderly relation to environmental consequences. However, the possibility remains that pause length and running rate were controlled separately rather than being integrated into one unit. The differences among subjects may have arisen because precise values of neither were necessary to meet the requirements. Thus,

whatever values happened to be followed by reinforcement could increase in frequency.

Treatment of the entire ratio and the pause as a single aspect of behavior parallels the usual approach to interresponse times involving pairs of responses. Both cases deemphasize the behavior occurring between the first and last events of the time interval. To pursue the parallel, ratio time is the interresponse time of an entire ratio where the first opportunity to respond is the starting point and the last response of the ratio is the end. Since, in addition, it is the sum of the individual interresponse times, ratio time also represents an integrated property of the complete sequence of interresponse times.

The present experiment fits with others in which entire fixed ratios are treated as individual responses and themselves are reinforced according to some schedule (Davison, 1969; Findley, 1962; Findley and Brady, 1965). Such procedures display the formal similarity between scheduling reinforcements for individual responses and for complete ratios. Using Kelleher's (1966) notation system, the present schedules were DRH(FR) and DRL (FR), in which the letters outside the parentheses indicate the schedule, and the letters inside the parentheses indicate the experimenter-defined response unit. The terms DRH and DRL stand for differential-reinforcement-of-high-rate and differential-reinforcement-of-low-rate, respectively. Where the typical DRH and DRL schedules involve individual interresponse times, the present requirements involved the time between the first opportunity to respond and the completion of the ratio.[2] Fantino (1968) also studied DRH and DRL schedules involving a number of responses

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[2]Findley (1962) and Kelleher, Fry, and Cook (1964) described a schedule in which reinforcement depended on a minimum pause duration before the first response as reinforcement of fixed-ratio behavior according to a DRL schedule. In their case, the critical interresponse time began with the first opportunity to respond and terminated with the first response. In the present studies, the interresponse time began with the first opportunity to respond but terminated with the last response of the ratio. Although either arrangement is appropriately called DRL(FR), the experiments show that the two forms of the schedule influenced behavior differently. For Findley and Kelleher *et al.* the most obvious effect was on the post-reinforcement pause. When, as in the present Exp. 2, the DRL requirement involved the entire ratio, the schedule modified both the pause and the post-pause response rate.

and found correspondence to the requirements. The point is that fixed ratios can be treated as units and show the sensitivity to a variety of schedules found with individual responses. In fact, the behavior for Birds 2, 55, and 56 under DRH(FR) in Exp. 1 was less erratic than that reported by Ferster and Skinner (1957) with DRH schedules based on individual interresponse times. Bird 54 revealed behavior similar to that observed by Ferster and Skinner.

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