

*PATTERNING WITH FIXED-TIME SCHEDULES OF
RESPONSE-INDEPENDENT REINFORCEMENT¹*

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Pigeons were first exposed to a schedule providing food when the time between successive key pecks (the interresponse time) exceeded a specified duration. When food then was presented at regular intervals independent of responding (fixed-time schedule), responses typically occurred at a steady rate in the periods between successive food presentations. Once the birds had been exposed to a fixed-ratio schedule, however, response rate under fixed-time schedules was positively accelerated. Variations in the sequence of conditions given different subjects indicated that the changes in patterning were due to the fixed-ratio schedule, rather than to the number of transitions from a response-dependent to the response-independent fixed-time schedule, to changed parameter values, or to prolonged experience with the fixed-time schedule. The effects of fixed-time schedules on patterning depended upon experimental history.

With fixed-interval (FI) schedules of food presentation, animals typically do not respond, and then display either positively accelerated or a steady rate of responding (Dews, 1970; Ferster and Skinner, 1957). The fixed-interval schedule requires that a response be emitted after the interval has elapsed for food presentation to occur. A fixed-time (FT) schedule differs in that it does not require a response; instead, food presentation occurs periodically independent of responding. The fixed-time schedule also often generates patterns consisting of an initial pause followed by positively accelerated responding (Appel and Hiss, 1962; Lattal, 1972; Zeiler, 1968), although responses occur less frequently in the FT schedule than in the FI and may even cease. The equivalence in patterns suggests that the placement of the reinforcing event in time—the characteristic shared by both schedules—is responsible for how responses are distributed in time.

The present procedures explored the generality of fixed-time schedule effects on patterning. The question of interest was whether the temporal distribution of responses observed previously would develop when responding initially was occurring at a low rate. In the

previous studies, response rate was substantial when the fixed-time schedule was instituted, because preliminary training was with fixed- or variable-interval schedules. In the present experiment, low rates were established by having food presentation depend on long interresponse times, and then the schedule was changed to fixed time.

METHOD

Subjects

Five White Carneaux pigeons were maintained at 80% of their free-feeding weights. None had served in experiments previously.

Apparatus

The experimental chamber resembled the single-key pigeon unit described by Ferster and Skinner (1957). The 2-cm diameter response key (R. Gerbrands Co.), operated by a force exceeding 0.12 N, was located 21.5 cm above the floor and was transilluminated by two 7.5-W white lamps. Purina Pigeon Checkers were presented occasionally for 4 sec through a 5.1-cm square aperture located 8 cm below the key. When the food hopper was activated, a 6-W white lamp illuminated the aperture and the keylights were turned off. A GE 25T10/1F lamp in series with a 300-ohm resistor provided dim general illumination except during the feeder cycles. White noise masked extraneous sounds.

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Table 1
Sequence of Schedules and Sessions With Each

P-109	P-115	P-117	P-118	P-120
IRT 5-sec (1-32)	IRT 30-sec (1-28)	IRT 5-sec (1-21)	IRT 15-sec (1-20)	IRT 15-sec (1-20)
FT 10-min (33-52)	FT 10-min (29-48)	FT 5-min (22-25)	FT 10-min (21-25)	FT 5-min (21-25)
FR 5-FR 100 (53-63)	FR 5-FR 100 (49-59)	IRT 30-sec (26-35)	IRT 30-sec (26-35)	FR 5-FR 100 (26-36)
FR 100 (64-84)	FR 100 (60-80)	FT 5-min (36-39)	FT 10-min (36-40)	FR 100 (37-46)
FT 5-min (85-89)	FT 5-min (81-91)	IRT 30-sec (40-46)	FR 5-FR 100 (41-51)	FT 5-min (47-51)
IRT 5-sec (90-109)	IRT 30-sec (92-111)	FT 5-min (47-50)	FR 100 (52-61)	IRT 30-sec (52-58)
FT 5-min (110-118)	FT 5-min (112-120)	FR 5-FR 100 (51-61)	IRT 30-sec (62-71)	FT 5-min (59-60)
IRT 5-sec (119-138)	IRT 30-sec (121-140)	FR 100 (62-67)	FT 10-min (72-74)	
FT 10-min (139-141)	FT 10-min (141-160)	IRT 30-sec (68-77)		
		FT 5-min (78-81)		

Procedure

For P-115 and P-120, key pecking was auto-shaped (Brown and Jenkins, 1968); P-109, P-117, and P-118 were trained to peck by successive approximations. All then had 30 food presentations, one after each key peck.

Table 1 shows the sequence of schedules. For all birds, the first schedule involved food presentation after a long interresponse time (IRT). Each response separated from the preceding response (a food presentation and the beginning of a session were treated as responses in this regard) by a time greater than t resulted in food presentation (IRT $>$ t schedule). The value of t was 5 sec for P-109 and P-117, 30 sec for P-115, and 15 sec for P-118 and P-120. The schedule then was changed to fixed time (FT): food was presented at regular intervals independent of responses. The transition from an IRT $>$ t to a fixed-time schedule was repeated twice with P-117 and once with P-118 before exposure to a fixed-ratio schedule. In the repetitions, the time parameter of the IRT $>$ t schedule was 30 sec.

Following these sequences of IRT $>$ t and fixed-time schedules, every n th response resulted in food presentation (a fixed-ratio schedule). Over 11 sessions, the fixed-ratio (FR) value was raised in increments of five responses up to 50 and then in increments of 10 responses up to 100. The FR 100 schedule was maintained for the sessions shown in Table 1. Then, P-109, P-115, and P-120 were exposed to a fixed-time schedule, but P-117 and P-118 were not. Next, all subjects were exposed to an IRT $>$ t followed by a fixed-time schedule. Finally, the sequence IRT $>$ t to fixed time was repeated once again with P-109 and P-115.

Sessions were conducted six days per week.

They lasted for 30 food presentations or until time requirements necessitated ending the session. The minimum duration was 2 hr.

RESULTS

Figures 1 and 2 show cumulative records of performance with the fixed-time schedules. In the first exposure (Figure 1, panel 1; Figure 2, P-120, upper record), responses occurred at a generally steady rate with few instances of positive acceleration between successive food presentations. Birds P-117 and P-118 (Figure 2, upper records) showed that a steady rate occurred even after two or three transitions from an IRT $>$ t to a fixed-time schedule.

As shown in Figure 3 (column of panels labelled "before FR"), quarter-life (Herrnstein and Morse, 1957a)—the proportion of the interval between successive food presentations required for the first 25% of the responses to occur—oscillated around 0.25 (the point indicated by the horizontal dashed line). Although quarter-life is a summary statistic, and a particular value can result from a variety of response distributions, a quarter-life of 0.25 corresponded with the generally steady rate occurring in the individual interfood intervals. The few values higher than 0.30 occurred in sessions in which there was positive acceleration in two or three interfood intervals and response rate was low in the remaining intervals. Figure 3 also shows that response rate was variable in the sessions under the fixed-time schedule. In some exposures rate decreased, in others it increased, and in still others it stabilized at a low level. Quarter-life is not shown for sessions when the response rate was less than 0.05 responses per second, because it did not seem to be a meaningful

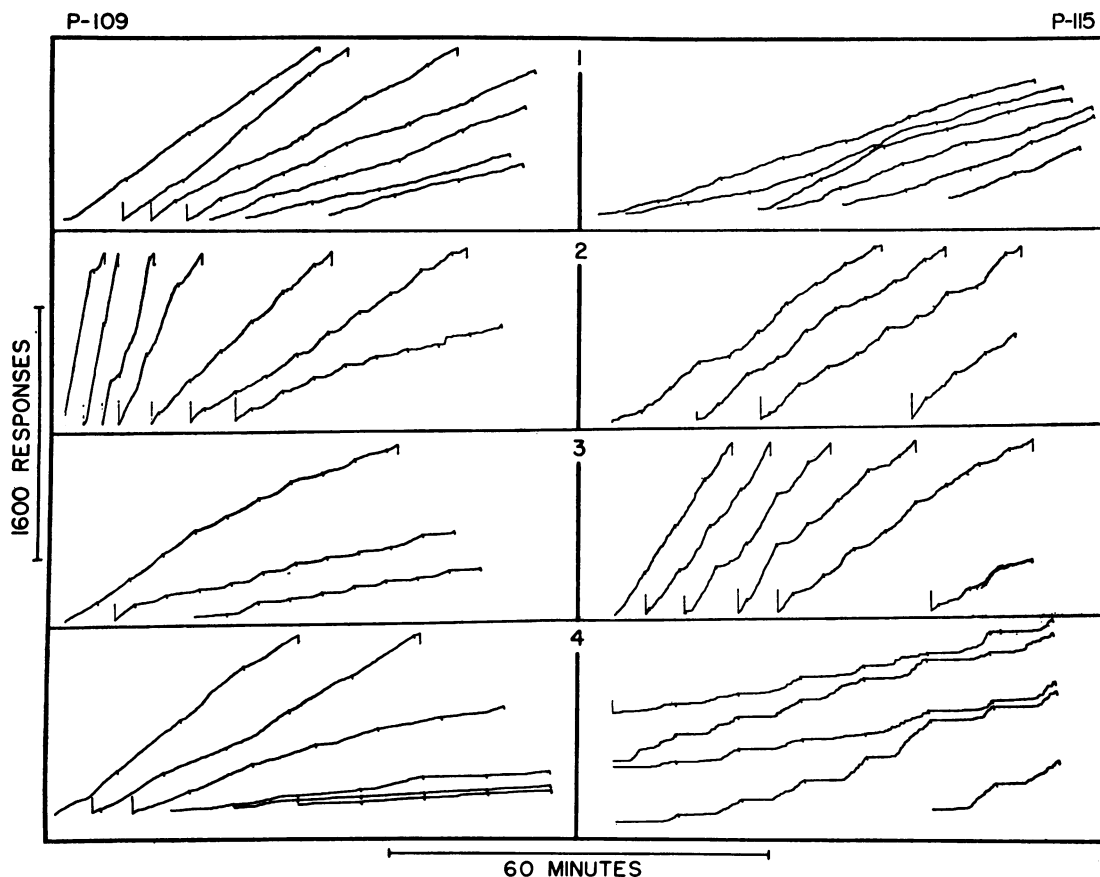


Fig. 1. Cumulative records for a complete session with the fixed-time schedule. Schedules 1 and 4 were FT 10-min; schedules 2 and 3 were FT 5-min. The schedules are numbered in their order of occurrence. Schedules 1, 3, and 4 followed $IRT > t$ training; schedule 2 followed training with FR 100. The session shown for P-109 is: schedule 1, Session 41; schedule 2, Session 85; schedule 3, Session 113; schedule 4, Session 139. For P-115: schedule 1, Session 43; schedule 2, Session 90; schedule 3, Session 117; schedule 4, Session 160. The response pen offset at each food presentation.

measure when overall rate was that low. The statistic was useful in offering some quantitative support for the conclusion generated by visual inspection of all cumulative records that rates were generally steady in all sessions in which there were enough responses to permit observing any pattern at all. In short, the patterns of positive acceleration that have been observed previously with fixed-time schedules did not occur (or occurred irregularly) when the birds initially were trained with an $IRT > t$ schedule.

Figure 1 (panel 2) shows that with fixed-time schedules imposed immediately after the FR 100 schedule, P-109 and P-115 often displayed positive acceleration. Quarter-life (Figure 3, column of panels labelled "FR") exceeded 0.32 by the third session, and was 0.42 in the final

session for P-115. Bird P-120, which also had the fixed-time schedule after FR 100, demonstrated comparable effects: quarter-life ranged from 0.45 to 0.57. Thus, in contrast with the previous exposures to the fixed-time schedule, positive acceleration now occurred reliably.

After all birds had experience with the FR 100 schedule, either with (P-109, P-115, P-120) or without (P-117, P-118) a fixed-time schedule immediately following, the schedule was changed to $IRT > t$ and then once again to fixed time. Figure 1 (panel 3) and Figure 2 (lower section of each panel) indicate that positive acceleration occurred frequently. Figure 3 (column of panels labelled "After FR") shows that quarter-life ranged from 0.30 to 0.62 in the last session for the different birds. Patterning under a fixed-time schedule imposed immedi-

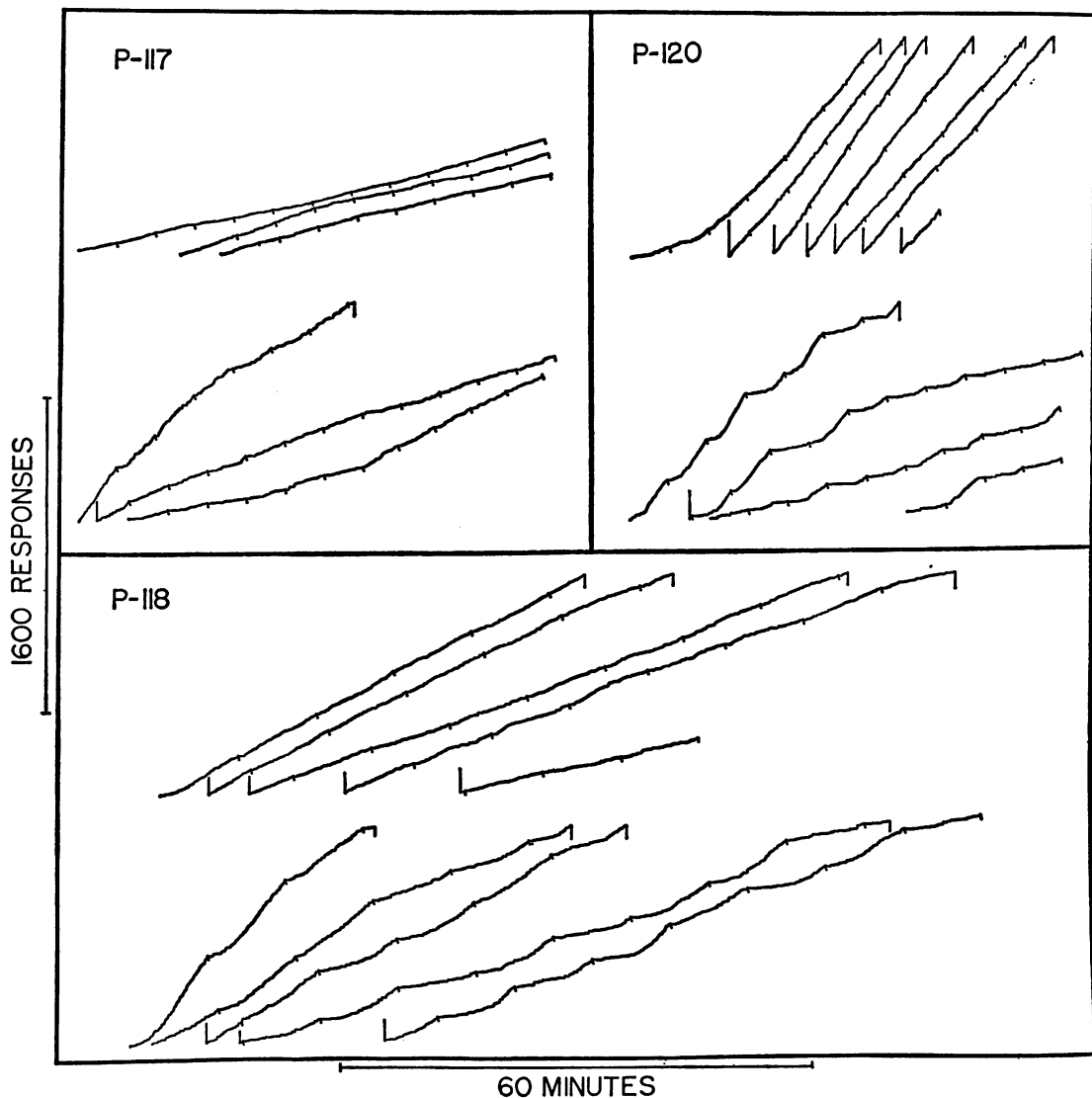


Fig. 2. Cumulative records for complete sessions with the fixed-time schedule following training with $IRT > t$ schedule. The upper record of each panel is for the last condition before exposure to the FR 100 schedule; the lower record was obtained following the history with FR 100. The upper records show Session 23 for P-117, Session 25 for P-118, and Session 24 for P-120; the lower records show Session 79 for P-117, Session 74 for P-118, and Session 60 for P-120. The response pen offset at each food presentation.

ately after an $IRT > t$ schedule had changed from a steady rate to consistent positive acceleration. The change was documented further by once again exposing P-109 and P-115 to an $IRT > t$ schedule followed by a fixed-time schedule. Figure 1 (panel 4) shows that P-115 revealed definite positive acceleration. Quarter-life (Figure 3, "After FR", unfilled circles) was 0.62 in the final session. Although the data of P-109 were equivocal by the second session due to the decrease in rate to 0.07 responses per

second, quarter-life was 0.32 in the first session.

DISCUSSION

For none of the birds was there more than an occasional instance of positive acceleration in a fixed-time schedule following $IRT > t$ training until they had been exposed to the FR 100 schedule. With all fixed-time schedules imposed after the FR 100 schedule, however, positive acceleration prevailed.

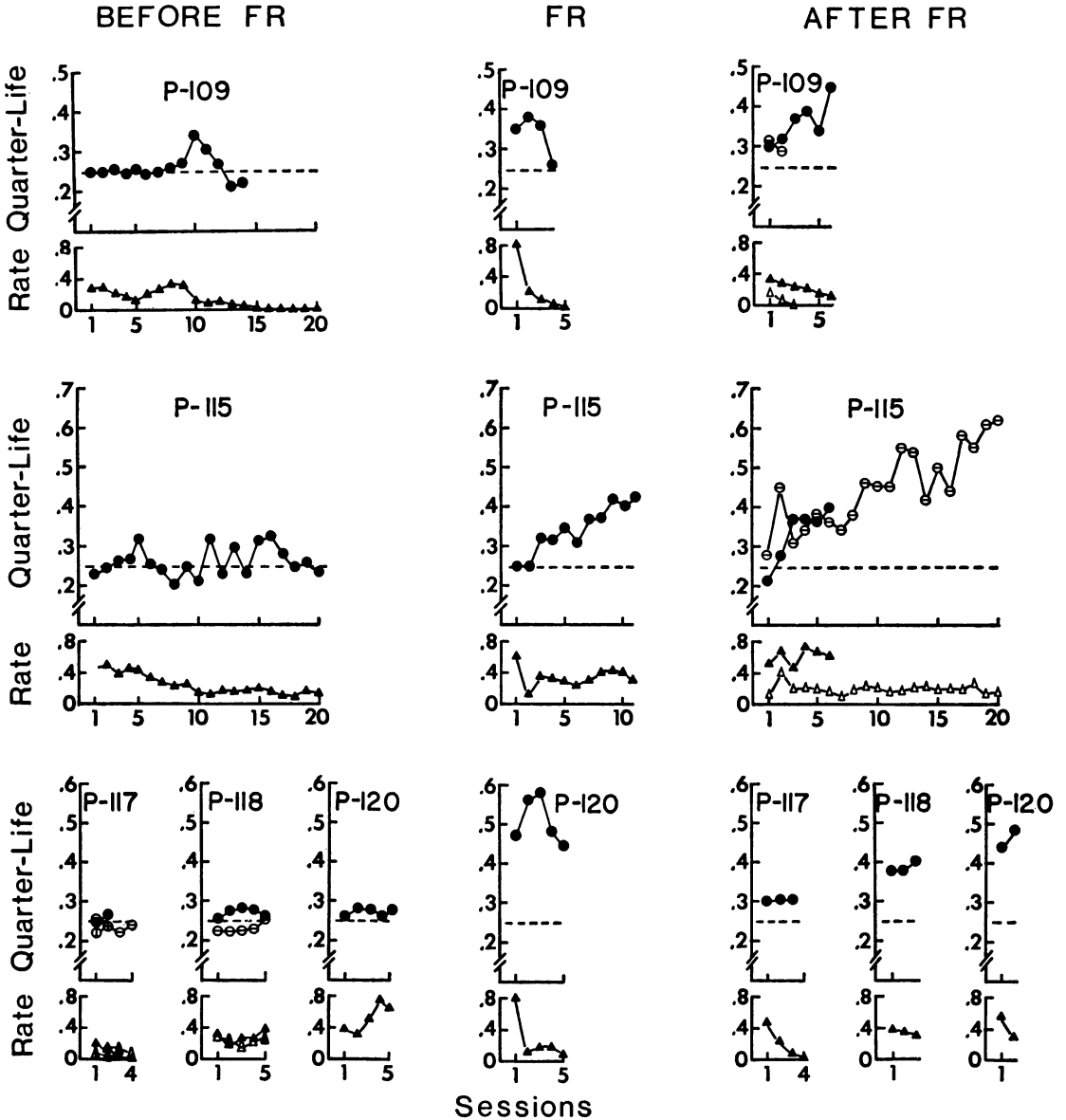


Fig. 3. Quarter-life and response rate (responses per second) for each fixed-time condition. Filled data points are for the first exposure, open data points with a horizontal line are for the second, and open data points with a vertical line are for the third. Conditions are arranged in columns based on whether they followed IRT > t schedules before exposure to FR 100 ("Before FR"), immediately followed FR 100 ("FR"), or followed IRT > t schedules after FR 100 training ("After FR").

Birds P-109 and P-115 had been studied before the others. The procedures used with P-117, P-118, and P-120 explored the generality of the effects observed initially and lead to the conclusion that exposure to the fixed-ratio schedule was responsible for the change in fixed-time schedule performance. (1) No subject showed reliable positive acceleration in any fixed-time condition before having the

fixed-ratio schedule, but all did thereafter. (2) Although P-109 and P-115 revealed positive acceleration upon exposure to a different fixed-time schedule than the one encountered initially, P-117, P-118, and P-120 never had different fixed-time schedule parameter values. Also, P-109 and P-115 showed positive acceleration under both FT 5-min and FT 10-min schedules. Therefore, parameter values in the ranges

studied could not be crucial. (3) Positive acceleration did not depend on having a fixed-time schedule immediately following the FR 100 schedule. Although P-109, P-115, and P-120 did have such a history, P-117 and P-118 did not. (4) Pattern changes were not simply the outcome of multiple transitions from response-dependent to response-independent schedules. Even with several transitions from an $IRT > t$ to a fixed-time schedule, P-117 and P-118 did not develop positive acceleration. (5) Changes in the response-dependent schedule were not in themselves sufficient. Bird P-117 had a sixfold change in t and P-118 had a twofold change between the first and second $IRT > t$ schedules. Positive acceleration still did not occur in an immediately succeeding fixed-time schedule. (6) Since the different subjects varied in the total number of sessions with a fixed-time schedule before positive acceleration prevailed, it was unlikely that the pattern was the outcome of sheer cumulative number of sessions. The successive number of sessions also was not critical, since P-117, P-118, and P-120 never had more than four or five sessions before the fixed-time schedule was discontinued, whereas P-109 and P-115 had not shown positive acceleration after 20 sessions. Taken together, these considerations indicated that it was the experience with the fixed-ratio schedule that was responsible for the patterns of positively accelerated responding subsequently established by the fixed-time schedule.

Although a history with the FR 100 schedule produced subsequent positive acceleration under fixed-time schedules, the data do not indicate what about this history was essential. The fixed-ratio schedule was used because there appeared to be no existing data on transitions from fixed-ratio to fixed-time schedules, not because of any hypothesis about the possible efficacy of such a condition. Some other response-dependent schedule might have had comparable effects.

Herrnstein and Morse (1957*b*) used a procedure that also provided information about the interaction of $IRT > t$ and fixed-time schedules. Instead of discontinuing the $IRT > t$ schedule, they maintained it and occasionally changed the key color from blue to yellow for 2 min. The $IRT > t$ schedule was in effect in the presence of both stimuli, but food was presented independent of responses after the first minute of yellow (FT 1-min schedule).

Although the most obvious effect was that response rate increased in the presence of yellow, positive acceleration often did occur during that stimulus. With a procedure like Herrnstein and Morse's, Henton and Brady (1970) also found rate enhancement by a stimulus correlated with a fixed-time schedule (FT 80-sec in their case). The records presented for one of their subjects (monkeys) indicated consistent positive acceleration in the presence of the stimulus. It may be that positive acceleration is characteristic of this joint schedule independent of history, since Herrnstein and Morse's pigeons had been exposed previously to other schedules, but Henton and Brady's monkeys seemed not to have had experimental experience. Thus, it is possible that the particular way in which a fixed-time schedule is imposed may be an important factor in determining the ensuing pattern.

The effects of scheduling events other than food according to a fixed-time schedule provides further evidence that particular experimental arrangements determine the effects of a stimulus. When Sidman, Herrnstein, and Conrad (1957) maintained responding with a continuous shock-avoidance schedule, the superimposition of a stimulus correlated with electric shock presentation according to a fixed-time schedule resulted in positively accelerated responding. Kelleher, Riddle, and Cook (1963) demonstrated that the fixed-time shock schedule would maintain this pattern even when the response-dependent schedule was discontinued. These experiments involving responding maintained by shock are important demonstrations that the effects of a schedule depend on a complex of conditions. As Morse and Kelleher (1970) discussed, the same schedule of shock presentation can either suppress or enhance responding. Not only is the schedule itself crucial, but experimental history plays a major role in determining what effects are seen. Staddon (1965) made a related observation when he found that stable response rates under two exposures to a particular $IRT > t$ schedule differed depending on what other $IRT > t$ schedules were interposed between the first and second exposures. The present experiment provided additional support for the importance of history: the effects of a fixed-time schedule of food presentation on patterning depended not only on the schedule but on history as well.

With reference to the present situation, it is unclear why history should influence patterning under a fixed-time schedule. Prevailing response rate did not seem to be a major factor, since similar initial rates were related to different patterns (initial and last exposures to a fixed-time schedule after $IRT > t$ training), and very different initial rates could result in similar patterns (fixed-time schedules after FR 100 and the final $IRT > t$ training). It is true that the fixed-time schedule, because it involves presentation of food without regard to behavior, places minimal constraints on the organism. Since whatever behavior occurs close in time to food presentation increases in probability (*e.g.*, Skinner, 1948), the particular response most affected might be key pecking or even some competing response that would preclude subsequent key pecking. Thus, the rate of key pecking is likely to decrease eventually, as it usually did when the fixed-time schedule was maintained for more than a few sessions. However, the patterns consisted of either a steady rate or positive acceleration despite changes in response rate. Two patterns, or perhaps even more, could follow from adventitious relations between responding and food presentation, but it is not evident that any particular pattern should be developed and maintained uniformly. Such consistency would follow more readily from an unchanging variable than from changing response-reinforcer relations. A variable having this constancy was the temporal regularity of food presentation.

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