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Third-Order Fixed-Ratio Schedules of Reinforcement

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INTRODUCTION

In general, a higher-order schedule of reinforcement consists of taking the sequence of behavior controlled by some schedule contingency, treating this sequence as a unitary response, and reinforcing this larger unit itself on some reinforcement schedule. The traditional reinforcement schedules are first-order ones -- e.g., a simple FR 40. However if the completion of each FR 40 produces only a brief stimulus change (say a flash of light), and several of these flashes are necessary to produce primary reinforcement, then we have a second-order schedule. For example, a schedule in which each completion of an FR 40 produces a light flash and three such flashes are required for primary reinforcement is a second-order schedule, notated as FR 3 (FR 40: flash). If we further expand this schedule so that each completion of this entire second-order unit produces only a brief stimulus change (say a tone), and require that three tones be produced to obtain primary reinforcement, then we have a third-order schedule, which is indicated as FR 3 [FR 3 (FR 40: flash): tone]. This procedure is diagrammed in Figure 1. Here we see that each completion of each FR 40 produces a flash of light; each third flash of light is accompanied by a tone, and each third tone is accompanied by food presentation. In this procedure, the total number of responses required for reinforcement is three times three times forty, or 360 responses.

However, this differs from a simple FR 360 in that various stimulus changes are programmed between primary reinforcements. Previous studies with second-order schedules have shown that such stimulus programming can influence both the tendency to perform (Findley and Brady, 1965) and the pattern of performance (Kelleher, 1966). In the present experiment, we have extended this investigation of stimulus functions to a third-order schedule. This allows an analysis of several different schedules of stimulus presentation within the same performance.

METHOD

Our subjects were two male Holtzman albino rats. Each was run daily, five days per week, in a standard operant conditioning chamber. Sessions were three to four hours long, with reinforcement consisting of the delivery of five 45 mg Noyes pellets. A print-out counter was used to record the time required to complete each of the first-order FR components involved in the overall schedule. The rats were initially trained to respond on an FR 20 schedule. Over a period of days this was changed to a second-order schedule and then to a third-order schedule. The third--order schedule with which the present experiments begin was FR 3 [FR 4 (FR 20: flash): tone]. In this schedule, each FR 20 completion produced a brief light flash. Each fourth flash was accompanied by a brief tone, and each third tone was accompanied by food presentation. The brief stimuli were of about 0.7 sec duration.

Once performance was stabilized on the third-order schedule, the effects of the various schedule parameters upon the pattern of performance were investigated by varying these schedule parameters. Also, the

functions of the various stimuli involved were investigated by switching to second-order and tandem schedules in which either only one of the stimuli or none of the stimuli were presented. This could be done without altering the response requirement for primary reinforcement; therefore alterations produced in the schedule performance by these changes could be attributed to the functions of the brief stimulus presentations. Table 1 shows the sequence of schedules which were used, and the number of reinforcement cycles on which the data is based for each rat. In Table 1 and in the figures which follow, the abbreviations S_1 and S_2 are used to represent light flashes and tone presentations respectively.

RESULTS

Figure 2 represents the performance of each of the two subjects on the first sequence of four third-order schedules. The horizontal of each graph represents successive components of the first-order FR. The vertical represents the median time in seconds to complete each of these components. In this and all subsequent figures the time for the initial component has not been shown, since it included the post-reinforcement pause time and therefore greatly exceeded the vertical time scale used in these figures. In all graphs the arrows indicate those FR components which were followed by tone presentation. (Tones also occurred at primary reinforcement, but are not indicated by arrows).

In Figure 2A we see for both animals a tendency for the component following the second tone presentation to require longer to complete than the neighboring components. Figures 2A, 2B and 2C show the effects

of increasing the size of the second-order fixed ratio value from FR 4 (Figure 2A), to FR 5 (Figure 2B), and to FR 6 (Figure 2C). This series of changes involves increasing the total number of FR 20 components required, and therefore the total number of bar presses required for reinforcement. It is apparent that as this schedule value is increased the tendency to pause following tone presentations increases. Pauses appear following the first tone presentation and those following the second tone presentation become more pronounced.

The transition from Figure 2C to 2D involved doubling the size of the first-order FR components from FR 20 to FR 40, and at the same time halving the value of the second-order FR from FR 6 to FR 3. Thus only half as many components were required, but each was twice as long as previously, so there was no change in the total requirement of bar presses for reinforcement. We see that the relative time required to complete the components following tone presentations was increased by this alteration in the schedule of stimulus programming.

In Figure 3 we can see the effects of the various stimuli involved in the third-order schedule performance. Figure 3A represents the performance when both lights and tones are programmed. For rat #81, substantial pauses occur following both the first and the second tone presentations. For rat #80, a substantial pause occurs following the second tone presentation, but only a slight disruption of the general trend of acceleration is produced by the first tone presentation. In Figure 3B, tones are no longer presented. Each FR 40 completion now produces a light flash, and nine light flashes are required for reinforcement. The pattern of pausing is completely abolished when the tones

are eliminated. In Figure 3C the situation is reversed; here the tones are presented following each third FR 40 completion, but no lights are presented following individual FR 40 completions. Here we see a difference between the two rats. For Rat #81, presentation of the tones is both sufficient and necessary for the pattern of pausing which was previously observed. However, for rat #80, presentation of the tones is necessary but not sufficient. That is, in the absence of the light presentation following each FR 40, rat #80 fails to exhibit substantial pausing following tone presentations. For both rats, when both lights and tones are again presented in Figure 3D, the pattern of pausing observed in Figure 3A is completely regained.

Figure 4 compares the third-order schedule in which both lights and tones are presented with a tandem schedule control condition in which no stimulus changes occur between primary reinforcements. Figure 4A shows the pattern of performance on the third-order FR 3 [FR 3 (FR 40)], in which pauses occur following each tone presentation. Figure 4B shows that on the tandem schedule, with no stimulus changes, the pattern of pausing is completely abolished. Rat #81 shows considerable variability in the early components of the tandem schedule. Figures 4C and 4D are simply a replication of this same procedure. It is interesting to note that when the stimuli were again presented in Figure 4C after the tandem schedule exposure of 4B, the pauses following tone presentations do not appear in the same magnitude seen in Figure 4A. In the replication of the tandem schedule condition in Figure 4D we obtain a monotonic acceleration across the nine FR 40 components of the schedule sequence.

In Figure 5 we see the results with several schedule manipulations after having raised the component ratio size from FR 40 to FR 80. This

raised the total response requirement for primary reinforcement from 360 to 720 bar presses. Figure 5A shows the performance on the third-order schedule with both stimuli being presented. Pauses reliably occur following each tone presentation. In Figure 5B, when a tandem schedule is employed, we see that the pattern of pausing is abolished. The pattern of pausing returns in apparently greater magnitude in Figure 5C when the stimulus presentations are reinstated. In Figure 5D is presented the performance on a second-order schedule of FR 9 (FR 80), in which a light flash was presented following each completion of an FR 80 component. It is possible to compare performance on this schedule with that on the tandem schedule represented in Figure 5B to assess the effect on performance of the light flash stimuli. If the light flashes are followed by pauses then we would expect that the rate on the second-order schedule would be lower than the rate on the tandem schedule. However, if the light flashes are serving to accelerate the performance without producing subsequent pauses then we would expect the rate on the second-order schedule to exceed the rate on the tandem schedule. If the stimuli produce both effects -- acceleration of the running rate and pauses following stimulus presentation, -- then the difference between the two schedules would be unpredictable. However, if the stimuli serve no function then the performances on the two schedules should be approximately the same. Therefore, differences between the two schedules would indicate that the stimuli are having an effect, although no differences between the schedules would not necessarily indicate that the stimuli are not having an effect. In examining the data in Figures 5B and 5D, it is apparent that for rat #80 the presentation of the light flashes results in an increased rate of response,

indicating that for that subject the light flashes were serving a conditioned reinforcing function. However, for rat #81 the performances on the tandem and second-order schedules do not differ appreciably. Therefore it is impossible to conclude whether the light flashes serve any function in the performance of that animal.

It can be concluded from the above data that stimulus programming in the manner of higher-order schedules of reinforcement can be used as an effective means of altering both the pattern of behavioral output and the rate of that behavior. Alterations in the parameters of the schedules involved in a higher-order schedule can successfully alter these characteristics of behavioral output while not altering the contingencies controlling the presentation of primary reinforcement.

TABLE 1

SEQUENCE OF SCHEDULES USED AND NUMBER OF REINFORCEMENTS ON WHICH THE DATA FOR EACH SCHEDULE IS BASED

Schedule	Rat #80	Rat #81
FR 3 [FR 4 (FR 20: S_1): S_2]	140	50
FR 3 [FR 5 (FR 20: S_1): S_2]	232	130
FR 3 [FR 6 (FR 20: S_1): S_2]	79	164
FR 3 [FR 3 (FR 40: S_1): S_2]	168	226
FR 9 (FR 40: S_1)	102	73
FR 3 [FR 120: S_2]	106	79
FR 3 [FR 3 (FR 40: S_1): S_2]	142	127
Tand FR 9 (FR 40)	96	31
FR 3 [FR 3 (FR 40: S_1): S_2]	221	118
Tand FR 9 (FR 40)	137	105
FR 3 [FR 3 (FR 80: S_1): S_2]	58	67
Tand FR 9 (FR 80)	31	39
FR 3 [FR 3 (FR 80: S_1): S_2]	42	36
FR 9 (FR 80: S_1)	69	61

REFERENCES

Findley, J. D. and Brady, J. V. Facilitation of large ratio performance by use of conditioned reinforcement. J. exp. Anal. Behav., 1965, 8, 125-129.

Kelleher, R. T. Conditioned reinforcement in second-order schedules. J. exp. Anal. Behav., 1966, 9, 475-485.

FR3 [FR3 (FR40:FLASH): TONE]: FOOD

40 RESPONSES ———— FLASH
3 FLASHES ———— TONE
3 TONES ———— FOOD

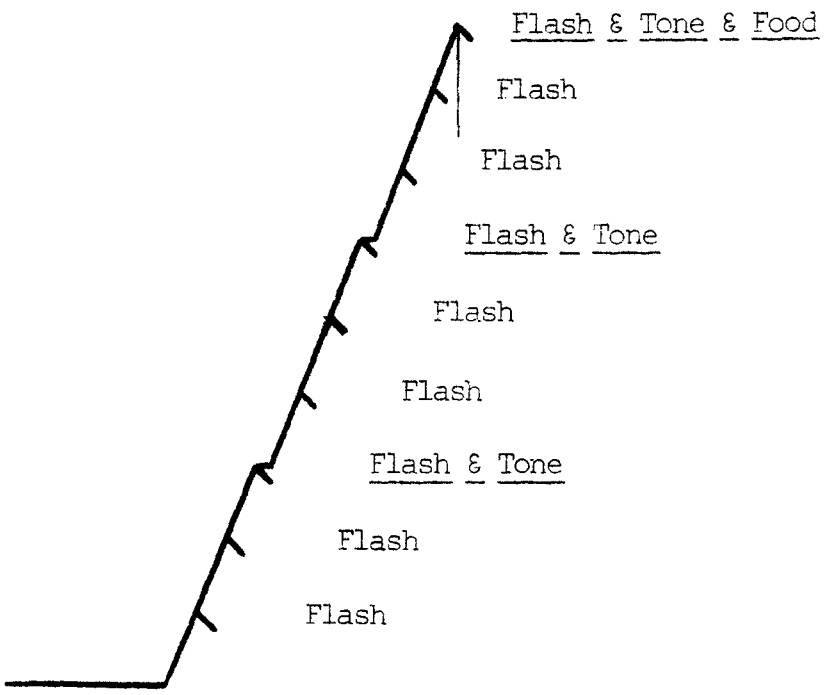

FIGURE 1

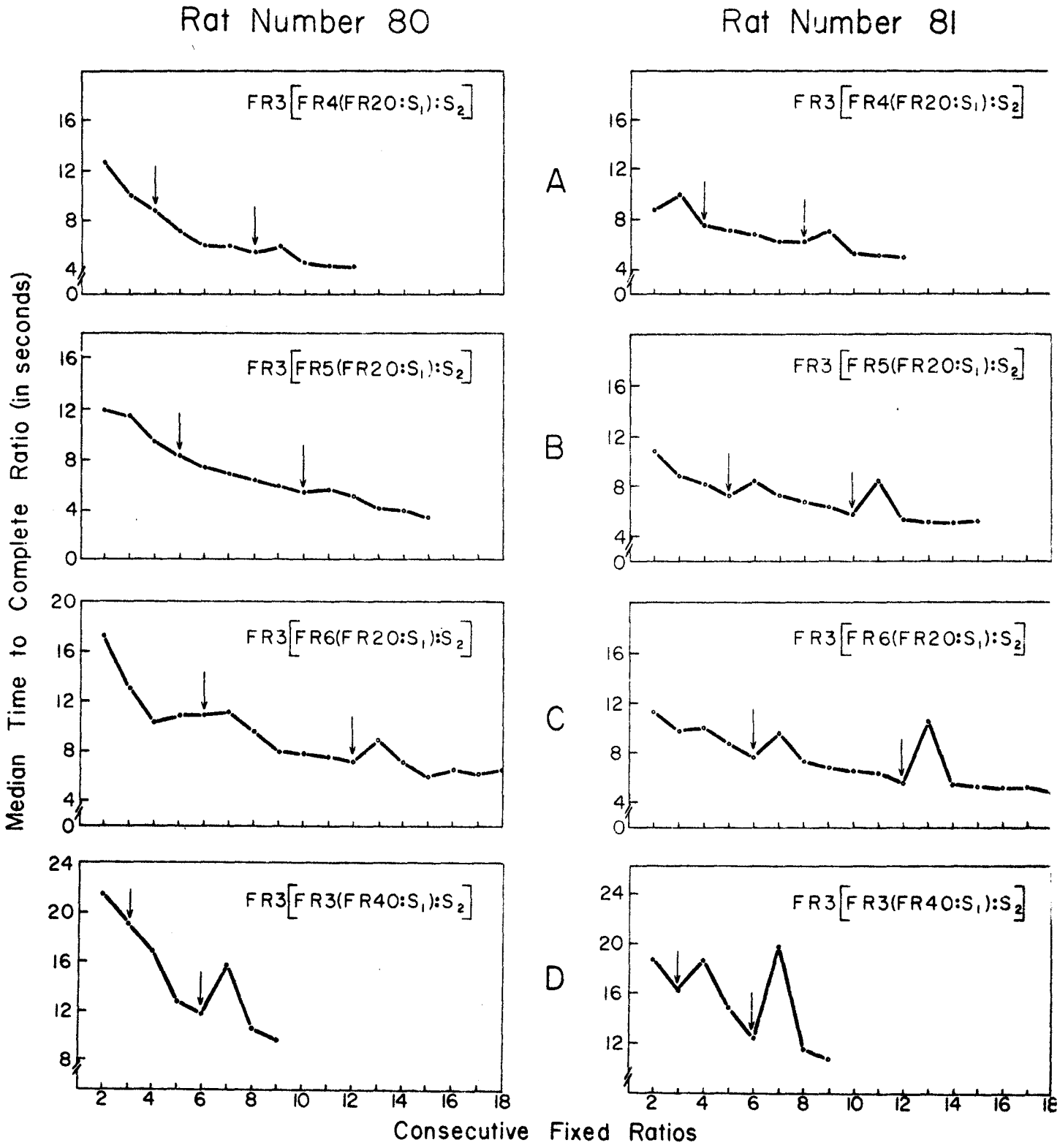
Rat Number 80
Rat Number 81
FR3[FR4(FR20:S1):S2]
FR3[FR5(FR20:S1):S2]
FR3[FR6(FR20:S1):S2]
FR3[FR3(FR40:S1):S2]
A
B
C
D
Median Time to Complete Ratio (in seconds)
Consecutive Fixed Ratios

FIGURE 2

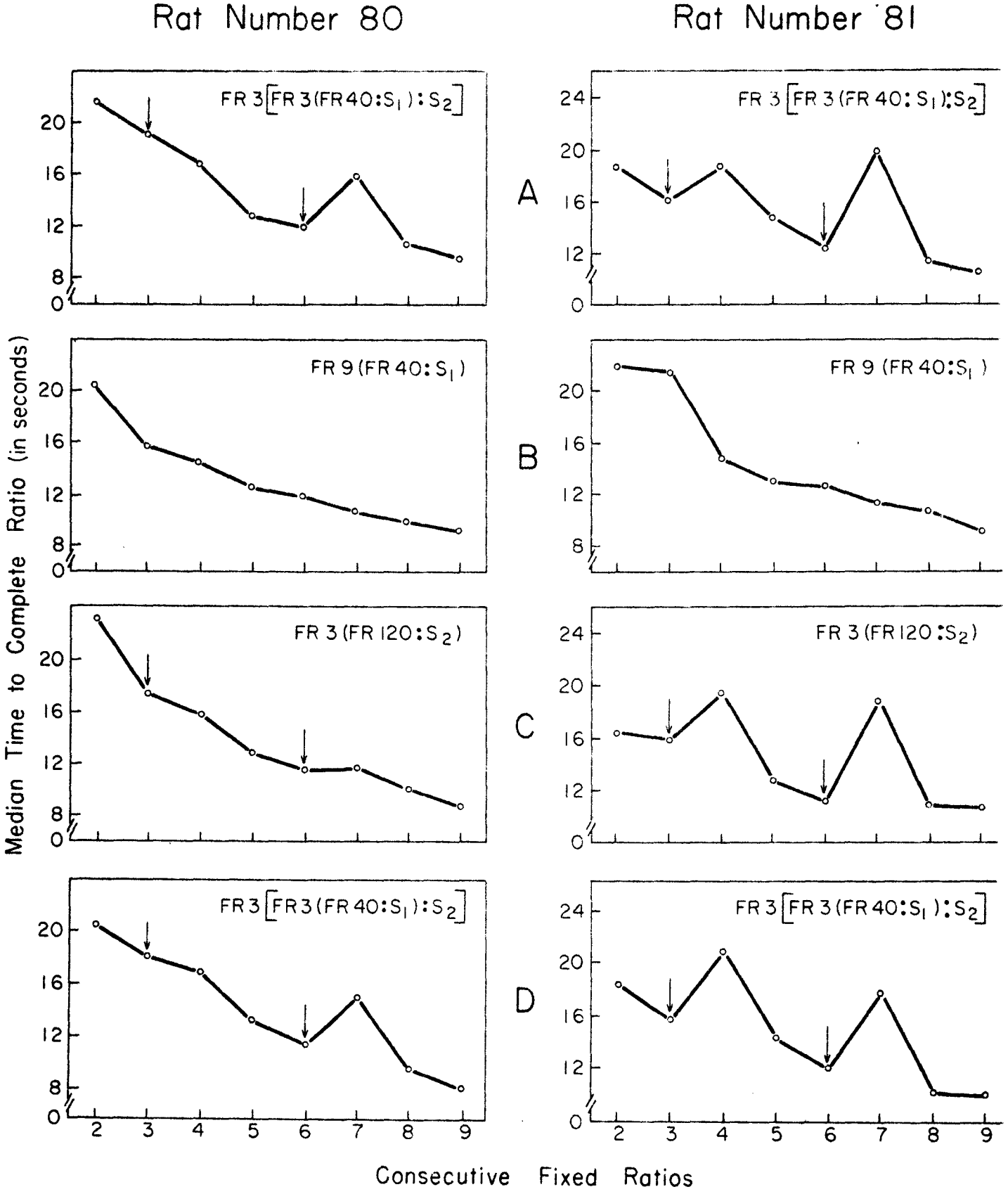
Rat Number 80
Rat Number 81
FR 3 [FR 3 (FR 40 : S1) : S2]
FR 9 (FR 40 : S1)
FR 3 (FR 120 : S2)
A
B
C
D
Median Time to Complete Ratio (in seconds)
Consecutive Fixed Ratios

FIGURE 3

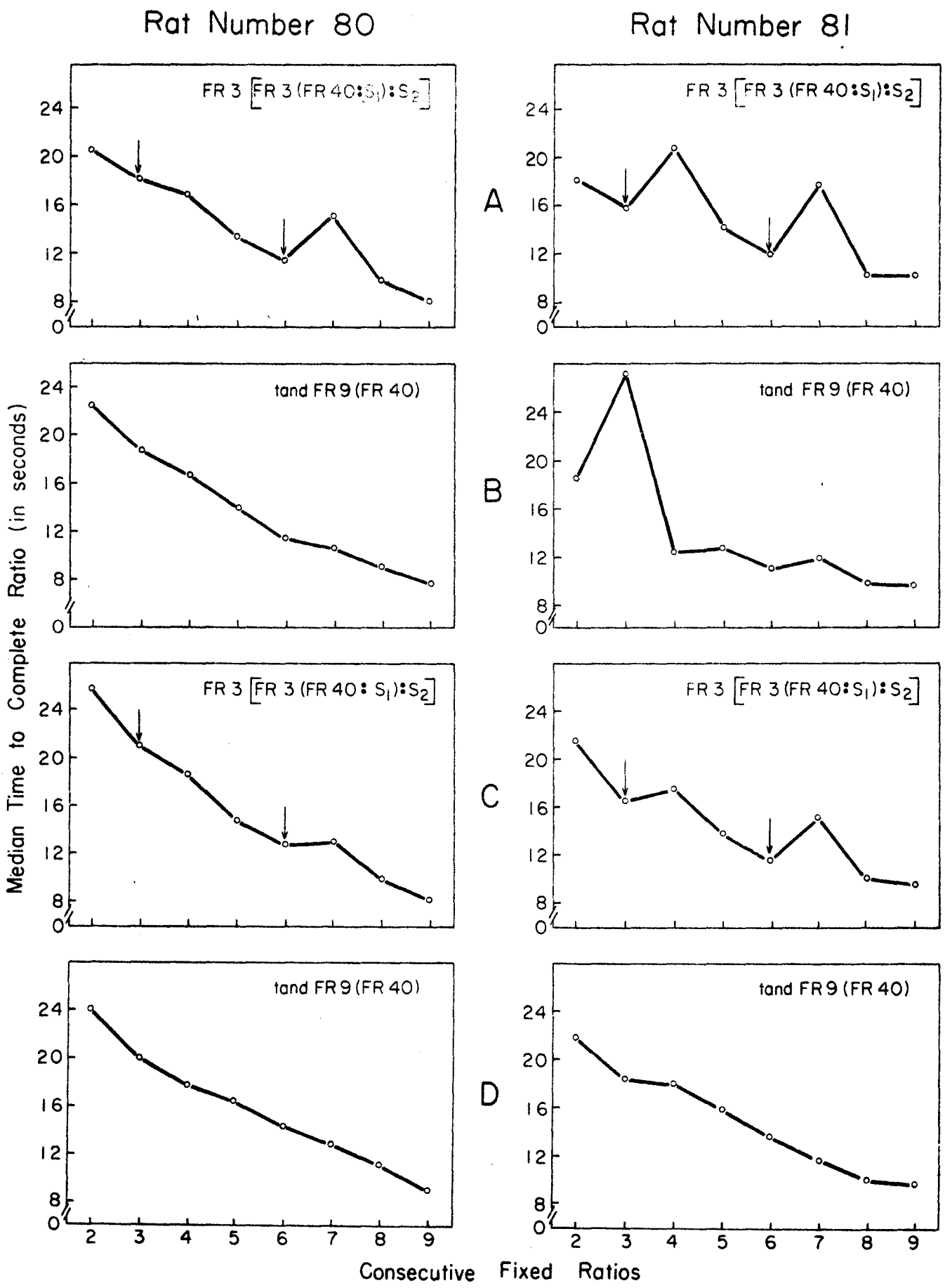
Rat Number 80
Rat Number 81
FR 3 [FR 3 (FR 40:S1):S2]
tand FR 9 (FR 40)
A
B
C
D
Median Time to Complete Ratio (in seconds)
Consecutive Fixed Ratios
0
8
12
16
20
24
2
3
4
5
6
7
8
9

FIGURE 4

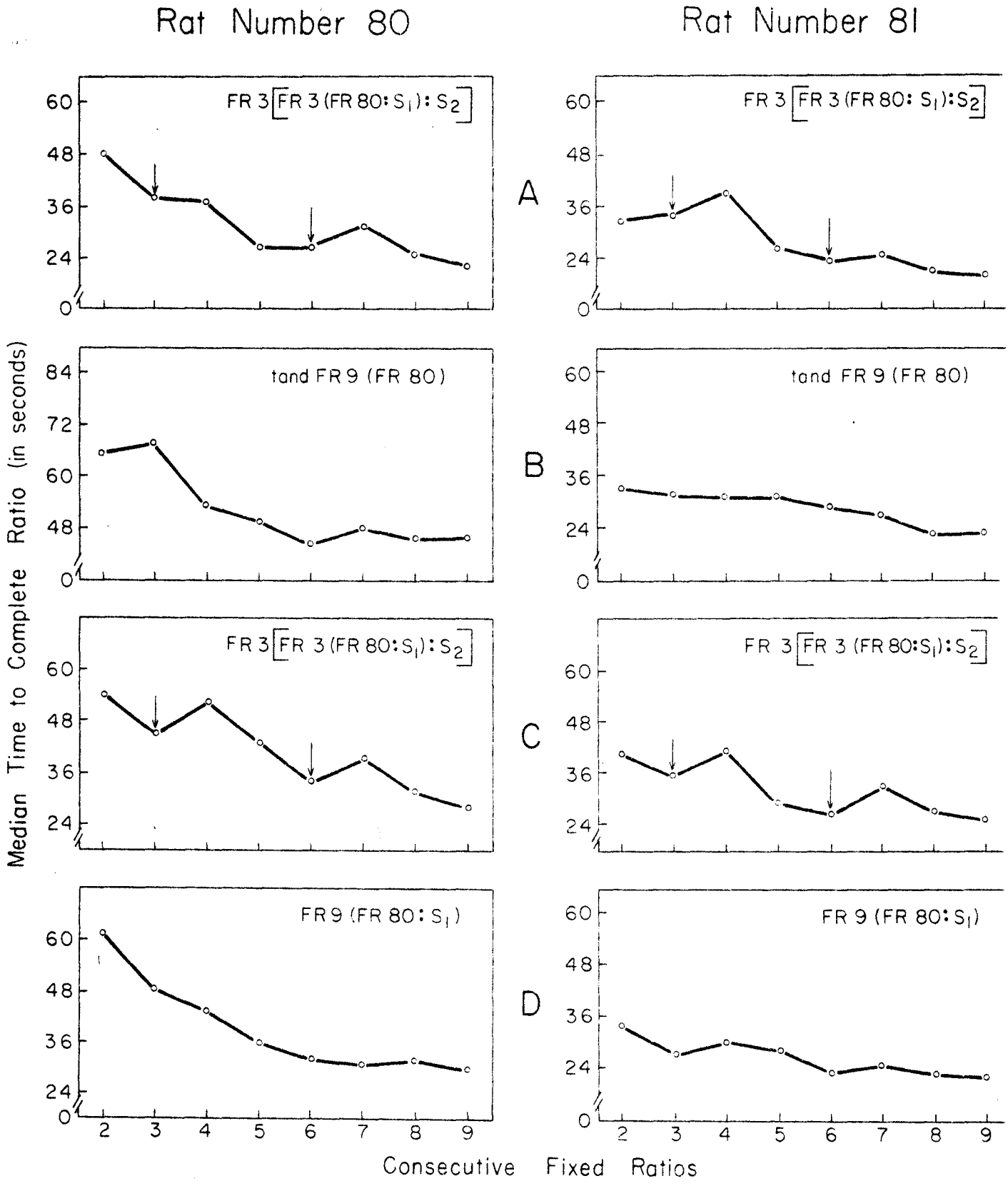
Rat Number 80
Rat Number 81
A
B
C
D
FR 3 [FR 3 (FR 80: S1): S2]
tand FR 9 (FR 80)
FR 9 (FR 80: S1)
Median Time to Complete Ratio (in seconds)
Consecutive Fixed Ratios

FIGURE 5