ACCURACY OF PERFORMANCE ON A MATCHING-TO-SAMPLE PROCEDURE UNDER INTERVAL SCHEDULES¹

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Correct matches on a matching-to-sample procedure were reinforced under fixed-interval, chained fixed-interval, and fixed-interval schedules with exteroceptive stimulus changes correlated with time since the last reinforcer (an added clock). For all four pigeons, accuracy changed within the fixed-interval and fixed-interval schedules with added clock, decreasing from the beginning of the interval to some point in the middle. The performance then became increasingly more accurate until the end of the interval. Under the chained schedules, accuracy also changed within the components. During the initial component, accuracy decreased from the beginning of the fixed interval to some point in the middle or at the end. During the middle component, the performance usually remained at an intermediate level of accuracy. During the terminal component, the initially inaccurate performance became increasingly more accurate throughout the interval. Systematic relationships between response rate and per cent error showed that all four pigeons performed most accurately at high rates. The accuracy of the performance at low rates was also quite high. These relationships held for all three types of schedules through an eight-fold variation in scheduled interreinforcement time.

The matching-to-sample procedure (Skinner, 1950; Ferster, 1960) consists of two parts. First, a peck on the illuminated center key darkens it and illuminates the two side keys. A peck on the side key, which is the same color as the previously illuminated center key, results in a brief presentation of the food-magazine light or the presentation of grain. This is a correct match. A peck on the side key that does not match the center key results in a brief timeout period. This is an error.

The present experiment investigated the patterns of correct matches and errors that were engendered by several varieties of fixed-interval schedules under a matching-to-sample procedure. Consistent patterns of responding engendered by the three kinds of schedules used in this study have been documented where the procedures involved a single key peck as the reinforced operant. However,

since the matching-to-sample procedure permits the organism to make errors that are never followed directly by reinforcement, as well as correct matches that are intermittently reinforced, several questions arise. What patterns of responding are engendered by the schedules? Do both correct matches and errors occur with the same pattern but at different rates? Does the accuracy of the performance change within the schedule? Does the most accurate performance occur immediately before reinforcement?

Clark and Sherman (1970) reported data where the performance on a matching-to-sample procedure was reinforced under a fixed interval. The rate of correct matches increased throughout the interval while the rate of errors occurred at a low and fairly constant rate. While accuracy was typically higher nearer the end of the interval than at the beginning, the accuracy became lower in the second or third quarter than at the beginning (also Ferster, 1960).

Several studies have involved reinforcing behavior resulting from complex procedures under fixed-ratio schedules of reinforcement. While procedures and parameters have varied considerably, the results were harmonious. The performance was least accurate immediately after reinforcement and became more

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accurate with each unit of the ratio that preceded reinforcement (Nevin, Cumming, and Berryman, 1963; Mintz, Mourer, and Weinberg, 1966; and Stubbs, 1968).

It appears that different types of schedules (interval *vs.* ratio) engender different patterns of accuracy. However, these differences could be a function of many different variables. One such variable is the length of the interreinforcement interval. In the experiments reported, the fixed-interval (FI) schedules had substantially longer interreinforcement periods than the fixed-ratio (FR) schedules.

The present study was a parametric investigation of the interreinforcement period. Three types of fixed-interval schedules were used, and the length of the fixed intervals was varied as a way to manipulate the time since reinforcement. The three types of schedules formed a continuum. The fixed-interval schedules required one correct match after the interval had elapsed, while the chained fixed-interval schedules required three correct matches (one after each component fixed interval) for food presentation. This type of schedule is denoted as chain FR 3 (FI *t*-sec) in the second-order schedule notation defined by Kelleher (1966). The chained schedules also were different from the regular fixed-interval schedules in that exteroceptive stimuli denoted the components. Therefore, the fixed-interval schedules with added clock furnished a bridge, since the behavioral requirement for reinforcement was one correct match, but exteroceptive stimuli marked the passage of time.

METHOD

Subjects

Four adult White Carneaux pigeons were housed in individual living cages and maintained at 80% of their free-feeding weights. Pigeon 72 and Pigeon 94 had complex experimental histories. Pigeon 126 and Pigeon 127 were experimentally naive.

Apparatus

An experimental chamber for pigeons (Fester and Skinner, 1957) was used. Three response keys were mounted horizontally in the center of the front panel 9.75 in. (24.7 cm) above the floor and 3 in. (7 cm) apart center

to center. Each key was illuminated separately by either a red or green 6-w bulb. Three pilot lights were arranged vertically to the right of the keys. Top to bottom they were blue, orange, and white. The aperture for the food magazine was below the center key. There was a white light inside the magazine. Primary reinforcement was a 6-sec exposure to grain in the illuminated magazine for Pigeons 94, 126, and 127, and an 8-sec exposure for Pigeon 72. The chamber was illuminated by two white 6-w bulbs located on the back panel. White noise was present in the experimental room.

Procedure

Preliminary training. Four pigeons were trained to match to sample. When a trial began, the center key was red or green. A peck on this key darkened it and illuminated the side keys immediately. One of the side keys was the same color as the sample and one was not. If the bird pecked the key that matched the sample, either grain was presented for 6 sec or the magazine light was turned on for 0.5 sec, depending on the schedule of reinforcement. When grain was presented in the illuminated magazine, the houselights were off. When the magazine light was presented alone, the key lights were off but the houselights remained on. If the bird pecked the key that did not match the sample, it received a timeout period for 5 sec, during which time the houselights and keylights were dark and reinforcement could not occur.

The sequences of sample stimuli and correct sides were arranged with a combination of two 12-trial Fellows sequences (Fellows, 1967) to which had been added two single alternations (*i.e.*, L,L,L,R,R,R,L,L,R,L,R,R,L,L,L,R,R,R,L,L,R,L,R,R,L,R,L,R). A correction procedure was in effect such that the color of the center key and the position of the colors on the side keys changed only after a correct match.

Each pigeon was exposed originally to small fixed-ratio schedules (FR 2 to FR 5) and then to small resetting fixed-ratio schedules (FR 3 to FR 8) such that each error reset the fixed-ratio counter. The pigeons received between 40 and 90 sessions of this preliminary training. At the end of this phase, the per cent error values had stabilized. The range over the last five sessions for each bird was the following: Pigeon 72, 3.4 to 5.4%; Pigeon 94, 7.9 to

14.1%; Pigeon 126, 9.0 to 12.8%; and Pigeon 127, 17.6 to 22.6%.

Experimental training. The schedules of reinforcement were fixed interval (FI $3t$), fixed interval with added clock (clock FI $3t$), and chained fixed interval [chain FR 3 (FI t)], where t took on four different values: 16, 32, 64, and 128 sec. Under the fixed-interval schedules, the behavioral requirement for reinforcement was a peck on the side key that matched the previously illuminated center key (*i.e.*, the completion of a correct match) after $3t$ sec had elapsed. The time that elapsed between the end of the $3t$ sec and the occurrence of a correct match was called the holding period. While each holding period contained only one correct match, it could contain any number of errors. The pilot lights were dark during these schedules. Only the three smallest values of t were used, providing FI 48-sec, FI 96-sec, and FI 192-sec. Each pigeon performed under all three fixed-interval schedules.

Under the fixed-interval schedules with added clock, the behavioral requirement was also the completion of one correct match after $3t$ sec had elapsed; however, the pilot lights were on during these schedules. The blue light was on for the first t sec of each interval. It then changed, independently of the pigeon's behavior, to orange for the next t sec and then to white for the last t sec and the holding period. The holding periods were of variable length because each one was terminated by the first correct match that occurred at any time after the interval had elapsed. During a timeout period, the pilot light remained on. Only the two largest values of t were used, providing clock FI 192-sec and clock FI 384-sec. Each bird performed under only one of these schedules.

Under the chained schedules, the behavioral requirement for reinforcement was three correct matches. During the first component of the chain (S3), the blue pilot light was illuminated. When the pigeon completed the first correct match after t sec had elapsed, the blue light went out and the orange light came on. After the completion of the first correct match after t sec had elapsed in this component (S2), the orange light went out and the white light came on. At the completion of the first correct match after t sec had elapsed in this component (S1), grain was presented. During a timeout period on the chained schedules, the pilot

light designating the component remained on. All four values of t were incorporated. Therefore, the following chained schedules were used: chain FR 3 (FI 16-sec), chain FR 3 (FI 32-sec), chain FR 3 (FI 64-sec), and chain FR 3 (FI 128-sec). Pigeons 94 and 127 performed under all four chained schedules, while Pigeons 72 and 126 performed under the three smallest chained schedules.

The order of presentation of the different schedules of reinforcement appears in Table 1.

Table 1
Order of Presentation of Schedules

Pigeon	Schedule	Sessions
72	FI 48-sec	21
	chain FR 3 (FI 16-sec)	25
	FI 96-sec	23
	chain FR 3 (FI 32-sec)	25
	FI 192-sec	23
	chain FR 3 (FI 64-sec)	36
	clock FI 384-sec	24
94	FI 48-sec	22
	chain FR 3 (FI 16-sec)	27
	FI 96-sec	23
	chain FR 3 (FI 32-sec)	24
	FI 192-sec	25
	chain FR 3 (FI 64-sec)	37
	chain FR 3 (FI 128-sec)	33
126	clock FI 192-sec	40
	FI 48-sec	21
	chain FR 3 (FI 16-sec)	26
	FI 96-sec	23
	chain FR 3 (FI 32-sec)	25
	FI 192-sec	27
	chain FR 3 (FI 64-sec)	41
127	clock FI 384-sec	24
	FI 48-sec	21
	chain FR 3 (FI 16-sec)	27
	FI 96-sec	22
	chain FR 3 (FI 32-sec)	25
	FI 192-sec	26
	chain FR 3 (FI 64-sec)	32
	chain FR 3 (FI 128-sec)	32
	clock FI 192-sec	44

The fixed-interval schedule always preceded the chained schedule at each value. This order was used because the response requirement was smaller for the fixed-interval schedule. The schedules with added clock were presented last for all birds. Each session lasted until there were 50 reinforcements when the value of t was 16 sec, 32 sec, and 64 sec. When t was 128 sec, a session was defined as 35 reinforcements. Total errors and total correct

matches were recorded for each twelfth of each interval and the holding period of the fixed-interval and fixed-interval schedules with

added clock, and for each fourth of each interval and the holding period of the chained schedules.

Fig. 1. The rate of correct matches and the rate of errors in each twelfth of the intervals. Each point is the median value of the last eight sessions under a schedule.

RESULTS

The performance under fixed-interval and fixed-interval schedules with added clock are presented first. In general, the rate of correct matches of all four pigeons increased over the interval while the rate of errors either passed through a maximum or became constant. The performance of each animal at corresponding portions of each schedule was consistent over a fourfold range in minimum interreinforcement time. The rate data for Pigeons 72 and 127 are shown in Figure 1. While the terminal absolute rate of correct matches is approximately twice as high for Pigeon 72 as for Pigeon 127, the performances of both animals reflect the pattern of increasing rates of correct matches for both types of fixed-interval schedules. The terminal rates for correct matches for three of the four pigeons decreased slightly at FI 192-sec; however, all four birds maintained about the same terminal rate of errors at all schedule values. These data for Pigeons 94 and 126 are presented in Table 2.

Two patterns of error rates emerged from the within-interval analyses. For example, the rate of errors of Pigeon 72 increased over the first half of the fixed intervals and then decreased slightly. On the other hand, the rate of errors of Pigeon 127 increased over the first half of the fixed intervals and then became

constant. The same two patterns of error rates were engendered by the schedules with added clock; however, the maximum rate of errors did not occur until the second quarter of the terminal stimulus. In addition to similar error rates, the rates of correct matches that occurred during this time period corresponded to the rates of correct matches engendered in the middle of the fixed intervals.

Since the patterns of rates of correct matches and of errors were different, the accuracy of performance changed within the fixed-interval and fixed-interval schedules with added clock. An appropriate measure of accuracy must take into account the total amount of responding as well as the absolute number of errors made during a given time period. Such a measure is per cent error, the ratio of errors to total trials times 100. Total trials are the sum of correct matches and errors. The per cent error functions for Pigeons 72 and 127 are shown in Figure 2. The plots of per cent error as a function of consecutive twelfths of the intervals passed through a maximum and then declined to a low level as the intervals elapsed for both types of schedule. The maxima under the fixed-interval schedules usually occurred after one third of the interval had elapsed, while the maximum per cent error under the fixed-interval schedule with added clock occurred near the end of the second stimulus period, or after two thirds of

Fig. 2. Per cent error for each twelfth of the intervals and the holding periods, H. The holding period was the additional time after the interval elapsed until the next correct match. Each point is the median value of the last eight sessions under a schedule. An exception occurred if the pigeon had made neither a correct match nor an error during a particular twelfth. In this case, the median involved between five and eight sessions.

Table 2
Measures of Performance on Fixed-interval and Clock Fixed-interval Schedules

Pigeon	Schedule	Twelfths of Intervals												H
		1	2	3	4	5	6	7	8	9	10	11	12	
94	FI 48-sec	0.9	4.2	6.9	9.6	12.9	12.0	16.2	16.8	17.7	18.6	19.5	18.0	—
		0.3	2.4	3.3	3.6	3.9	3.9	4.8	4.2	5.1	4.2	4.5	4.8	—
		6.3	29.9	29.9	25.7	25.4	22.8	20.9	20.8	21.3	18.2	17.9	22.7	15.3
	FI 96-sec	1.2	3.1	4.1	6.5	8.7	13.2	15.3	17.7	20.4	22.2	23.1	22.6	—
		0.5	1.8	2.1	3.6	4.7	4.8	4.1	4.1	3.3	3.8	3.0	3.0	—
		28.0	32.0	33.3	36.8	33.4	28.0	21.4	17.8	13.7	15.0	11.8	11.6	9.1
126	FI 192-sec	0.8	1.9	5.0	7.1	10.1	11.8	14.2	14.7	17.5	18.8	20.6	21.7	—
		0.5	1.1	2.7	3.7	4.4	4.5	4.4	4.4	4.1	3.7	3.8	3.2	—
		33.9	31.1	34.4	34.8	29.0	26.9	24.4	22.6	18.6	16.5	15.6	12.9	10.7
	clock FI 192-sec	1.4	1.1	1.4	1.2	0.8	2.0	3.5	5.1	8.8	14.9	21.9	24.9	—
		0.5	0.4	0.4	0.3	0.3	0.8	1.3	2.5	4.1	5.2	3.8	2.3	—
		22.1	24.3	19.1	17.1	34.4	29.2	33.1	33.7	32.4	25.8	14.6	8.5	5.7
126	FI 48-sec	0.3	3.0	5.4	6.0	6.9	8.7	10.5	13.2	13.5	16.8	17.4	18.9	—
		0.0	1.5	2.4	3.0	4.2	4.2	3.9	3.9	3.6	3.3	2.4	3.3	—
		16.7	29.2	30.1	34.5	36.8	29.8	27.2	23.4	22.1	15.5	11.4	13.9	17.4
	FI 96-sec	0.3	1.4	3.5	4.7	7.4	10.6	11.4	13.9	16.2	19.6	18.7	19.6	—
		0.0	0.8	1.7	2.6	3.6	3.9	3.9	3.5	3.3	2.6	2.4	2.4	—
		0.0	24.9	32.7	31.5	31.2	25.4	25.4	18.8	16.9	11.6	10.7	11.1	8.3
126	FI 192-sec	0.8	2.0	4.4	6.3	7.3	8.4	9.1	10.1	10.2	11.6	12.1	12.3	—
		0.3	1.7	2.7	3.5	4.0	4.1	4.1	4.2	4.2	3.8	4.4	4.1	—
		27.5	44.7	41.0	35.8	35.1	30.7	31.2	30.3	28.2	24.4	26.4	24.2	21.3
	clock FI 384-sec	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.5	3.1	6.8	10.0	11.8	—
		0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.7	2.4	4.1	4.3	4.3	—
		*	*	*	*	46.5	42.9	52.8	58.9	44.0	37.0	31.1	27.8	15.7

*Each value is the median of the last eight sessions under a schedule. An exception occurred if the pigeon had not responded at all during a particular time period. In this case, the median involved between five and eight sessions. If more than three of the eight values were indeterminate, no value is given.

the interval had elapsed. The per cent error values for Pigeons 94 and 126 are given in Table 2. The functions for these birds are similar to those for Pigeons 72 and 127. While there was generally an increase in per cent error followed by a decrease during the interval, the intersession ranges of per cent error became smaller as the interval elapsed. For example, the largest change represented in Figure 2 was for Pigeon 72 under FI 96-sec. The average intersession range for the first quarter of the interval was 68 percentage points and the average intersession range for the last quarter of the interval was 10 percentage points.

The chained fixed-interval schedules required three correct matches: one after each component fixed interval had elapsed. Only the third interval was followed by grain presentation. Over an eightfold range in scheduled interreinforcement time, the graphs of rates and per cent error had similar shapes for the corresponding portions of each component of the chained schedules. Figure 3 presents the rate data for Pigeons 94 and 126. Generally, the rate of correct matches increased within each component. The performances appeared to be under the control of the chain stimuli because the rates of correct matches at the beginning of the terminal component under every chained schedule decreased for all four animals. The data for Pigeons 72 and 127 are presented in Table 3.

With only a few exceptions, the rates of errors increased monotonically throughout the first two components of the chains. Generally, the rates of errors decreased during the terminal components. A different result occurred for Pigeon 126 under chain FR 3 (FI 64-sec): during the first three quarters of the terminal stimulus period, the rate of errors increased. However, the performance of this bird was weakly maintained under this value of the chained schedule. Very long pauses developed in S3, such that there were only 50 reinforcements in a 14-hr session. It was necessary to increase the duration of the food presentation to 11 sec during this schedule to maintain any performance at all.

Accuracy of performance varied within the chained schedules. The per cent error data are presented in Figure 4 for Pigeons 94 and 126 and in Table 3 for Pigeons 72 and 127. In most cases, accuracy decreased throughout the initial component, S3. During S2 the perform-

ance remained moderately inaccurate (*i.e.*, between a quarter and a third of the responses were errors). In a few instances, accuracy increased slightly as the middle component of the chain elapsed. For every bird under every chained schedule, the performance was more inaccurate at the beginning of S1 than at the end of S2. As the terminal component elapsed, the performance became increasingly more accurate. Again, as under the fixed-interval and fixed-interval schedules with added clock, the intersession ranges of per cent error became smaller with each successive component of the chain. For example, the largest change represented in Figure 4 was for Pigeon 126 under chain FR 3 (FI 64-sec): the average intersession range for S3 was 72 percentage points and the average intersession range for S1 was 17 percentage points. In spite of the procedural changes mentioned above for this bird on this schedule, the per cent error function resembled those for the other chained schedules, although the overall level of inaccuracy was greater.

Comparison of the per cent error graphs (Figures 2 and 4) with the response rate graphs (Figures 1 and 3) suggested a systematic relationship between overall response rate and per cent error, occurring under different schedule conditions. This relationship can be revealed in scatter plots of rate and accuracy. The scatter plots of the per cent error at different rates under the fixed-interval and fixed-interval schedules with added clock are shown in Figure 5 for all four pigeons. Since rate usually increases monotonically in the interreinforcement period of fixed-interval schedules, the abscissae of Figures 2 and 5 are almost equivalent. The general trend is the same for each animal: at low rates of responding (*i.e.*, few trials were completed in a twelfth of the interval) and at high rates of responding, the per cent error values are lower than at intermediate rates of responding. In other words, each pigeon was most inaccurate when it was responding at an intermediate rate and was most accurate when it was responding at a high or at a low rate. The fixed-interval schedules with added clock provided data at very low response rates that generally followed the same pattern as the regular fixed-interval data.

The scatter plots of the data from the chained schedules are presented in Figure 6 for all four birds. The ordering of the points

Fig. 3. The rate of correct matches and the rate of errors in each quarter of each component fixed interval in the chained schedules. Each point is the median value of the last eight sessions under a schedule.

Table 3
Measures of Performance on Chained Fixed-Interval Schedules

Pigeon	Schedule	Quarters of Schedule Components															
		S3				S2				S1							
		I	2	3	4	H	I	2	3	4	H	I	2	3	4	H	
72	chain FR3(FI 16-sec)	Matches/Min	0.0	0.0	1.5	5.4	—	2.4	9.3	11.7	13.8	—	6.0	17.7	27.3	33.0	—
		Errors/Min	0.0	0.0	0.3	0.6	—	0.3	2.7	2.7	3.0	—	3.0	3.6	1.2	0.6	—
		Per cent Error	*	*	11.1	10.5	32.0	9.7	20.9	16.9	19.3	13.1	30.4	15.9	4.1	1.7	1.0
	chain FR3(FI 32-sec)	Matches/Min	0.3	1.2	2.3	3.5	—	3.8	7.4	10.2	13.2	—	4.4	13.0	24.1	28.8	—
		Errors/Min	0.2	0.3	0.6	1.2	—	1.4	2.4	2.9	2.9	—	3.0	3.6	2.1	1.1	—
		Per cent Error	20.0	16.7	18.1	24.5	36.7	26.5	24.5	20.5	17.6	13.1	40.4	21.8	7.8	3.3	2.0
	chain FR3(FI 64-sec)	Matches/Min	0.1	0.3	0.9	1.4	—	1.9	5.4	7.2	8.5	—	2.3	8.2	16.6	24.7	—
		Errors/Min	0.0	0.2	0.2	0.5	—	0.9	1.8	2.5	2.4	—	1.4	3.7	2.9	1.6	—
		Per cent Error	0.0	13.1	21.0	22.9	30.1	27.3	22.9	24.6	21.3	20.0	32.1	30.7	12.9	6.7	3.8
	chain FR3(FI 16-sec)	Matches/Min	0.0	0.3	2.1	4.2	—	3.0	5.4	6.9	8.7	—	4.8	10.2	13.8	15.6	—
		Errors/Min	0.0	0.3	1.5	3.9	—	2.1	4.8	4.2	4.8	—	2.7	5.7	4.5	5.7	—
		Per cent Error	*	25.0	38.8	48.2	44.1	42.5	40.8	36.0	35.8	30.0	36.8	35.2	23.1	28.3	9.9
127	chain FR3(FI 32-sec)	Matches/Min	0.3	0.2	1.4	3.9	—	2.4	5.6	7.7	8.4	—	5.3	10.0	12.9	15.3	—
		Errors/Min	0.2	0.2	1.1	3.3	—	1.4	4.1	4.7	4.8	—	4.2	5.4	4.4	3.5	—
		Per cent Error	10.0	50.0	44.0	47.4	31.5	37.3	40.3	37.8	37.3	32.9	44.3	35.1	25.1	17.9	13.8
	chain FR3(FI 64-sec)	Matches/Min	0.4	0.5	0.9	1.6	—	1.7	4.8	6.8	8.3	—	3.5	8.2	12.8	14.9	—
		Errors/Min	0.3	0.1	0.5	1.1	—	1.4	2.6	4.1	4.9	—	2.8	4.8	3.7	3.1	—
		Per cent Error	37.5	20.0	44.7	39.8	32.4	41.1	38.1	36.7	35.9	28.7	45.8	37.7	22.1	16.0	14.6
	chain FR3(FI 128-sec)	Matches/Min	0.5	0.5	0.5	0.7	—	2.3	3.0	3.9	6.2	—	3.2	5.8	11.4	16.0	—
		Errors/Min	0.6	0.6	0.5	0.7	—	2.0	2.7	3.6	3.4	—	2.6	4.3	4.2	2.5	—
		Per cent Error	49.0	57.8	40.4	44.8	46.0	46.0	47.4	43.6	38.4	40.9	44.4	42.0	25.4	11.7	11.8

*Each value is the median of the last eight sessions under a schedule. An exception occurred if the pigeon had not responded at all during a particular time period. In this case, the median involved between five and eight sessions. If more than three of the eight values were indeterminate, no value is given.

Fig. 4. Per cent error for each quarter and holding period, H, or each component fixed interval in the chained schedules. The holding period was the additional time after the interval elapsed until the next correct match. Each point is the median value of the last eight sessions under a schedule. An exception occurred if the pigeon had made neither a correct match nor an error during a particular time period. In this case, the median involved between five and eight sessions. If more than three of the eight values were indeterminate, no point was plotted.

from left to right has lost some of the sequential properties that existed in Figure 5 because the rate under the chained schedules usually increased within each component and then decreased at the beginning of the next component. Although these data points do not describe a single curve to the same extent as those in Figure 5, the general trend is the same: all four birds performed most inaccurately at intermediate rates of responding and performed most accurately at high rates. The accuracy of the performance at low rates was also quite high. These relationships held over three types of schedules of reinforcement and over an eightfold range in scheduled interreinforcement time.

DISCUSSION

This study investigated changes in the accuracy of the performance of pigeons under a matching-to-sample procedure. Several previous studies have dealt with similar procedures and may be compared with the present study. Ferster (1960) reported that the performance of two pigeons under a matching-to-sample procedure was the most inaccurate during the second quarter of the FI 10-min component of a multiple FI FR schedule. Clark and Sherman (1970) reported that performance became very accurate by the end of FI 8-min. In some

conditions of their experiment, accuracy decreased during the middle part of the interval.

The fixed-interval data of the present experiment can be compared directly with these studies. Although the values of the fixed-interval schedules in this experiment were shorter than those of the previous studies, all four pigeons were more inaccurate during the middle parts of the fixed intervals. An interesting point is that this effect would not be revealed for any pigeon on any schedule if the per cent error were calculated for thirds of the fixed-interval periods. However, when the per cent error was calculated for twelfths of the fixed intervals, the curves for every bird on every schedule passed through a maximum. The maxima did not all occur during the same twelfth, but they were all during the second to the seventh twelfths from the beginning of the intervals.

Each pigeon performed under one fixed-interval schedule with added clock. This type of schedule was chosen because it has the same response requirement as the fixed-interval schedules and the same exteroceptive stimuli as the chained schedules. The patterns of correct matches engendered by the schedules with added clock resembled those reported by Segal (1962): very low rates occurred before the terminal stimulus. If the terminal stimulus period is itself considered as a fixed-interval

Fig. 5. Systematic relationships between response rate and per cent error under the fixed-interval and fixed-interval schedules with added clock. Each point is one of the median per cent error values from the last eight sessions under a schedule.

schedule, the per cent error values are similar to those engendered by corresponding portions of the regular fixed-interval schedules.

The last part of this study involved chained fixed-interval schedules in conjunction with the matching-to-sample procedure. The chained schedules differed from the fixed-interval schedules by the addition of two response requirements at the end of the first and second components of the chains and by the addition of stimuli in each component (Golub, 1958). The results of adding the stimuli and tripling the response requirement while leaving the minimum interreinforcement time constant was to change the shape of the per cent error curves in an important way. While

the values of per cent error for the first two components of the chained schedules did not look very different from those of the first two thirds of the fixed-interval schedules, the values for the terminal component showed a marked change from the last third of the fixed interval. The large increases in per cent error at the beginning of S1 showed control by the terminal stimulus.

The mean rate changes of key pecking under fixed-interval schedules has been described as a scallop, *i.e.*, a pause after reinforcement followed by increasing rates of responding (Ferster and Skinner, 1957). Dews (1962 and 1965) reported a series of experiments in which the fixed interval was interrupted by timeout pe-

Fig. 6. Systematic relationships between response rate and per cent error under the chained schedules. Each point is one of the median per cent error values from the last eight sessions under a schedule.

riods. In spite of these interruptions, all four pigeons that he studied maintained positively accelerated patterns of responding. The present experiment may be compared with Dews' procedure. The schedules in this study may be thought of as fixed intervals that were interrupted a variable number of times per interval. Because larger units of behavior than single pecks may be reinforced on various schedules (Findley, 1962), correct matches may be considered analogous to key pecks and errors may be considered analogous to the timeout periods (an error was, in fact, followed by a timeout period). The results show that for all four birds under three varieties of fixed-interval schedules, the general pattern of increased number of responses over the interval was maintained for correct matches.

Millenson, Hurwitz, and Nixon (1961, p. 247) and Catania and Reynolds (1968, pp. 356-357) have reported nearly constant average fixed-interval rates of responding over a range of 15 to 240 sec. Catania and Reynolds did an even more detailed analysis, which revealed that fairly similar rates occurred at equivalent times (relative time since reinforcement) in fixed intervals ranging from 30 to 200 sec. The rate data for correct matches under the fixed-interval schedules bear a strong resemblance to those reported previously. There was even a decline in the terminal rate at the largest value as found by Catania and Reynolds. These data suggest that pattern of occurrence of the reinforced unit of behavior is a function of the schedule of reinforcement and not of the size or complexity of the unit.

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