*PREFERENCE FOR FIXED-INTERVAL TERMINAL LINKS
IN A THREE-KEY CONCURRENT CHAIN SCHEDULE¹*

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Pigeons were trained on three-key concurrent chain schedules in which the initial links were variable-interval schedules and the terminal links were fixed-interval schedules. In the first experiment, the initial links were all equal and the terminal-link schedule on one key only was varied. In the second part of the experiment, the terminal-link schedules were all fixed, but different, and the initial-link schedule on one key was varied. Relative response rates in the initial links did not match either the relative arranged, nor the relative obtained, terminal-link reinforcement rates. The relations between independent and dependent variables in three-key concurrent chains were similar to, but not identical with, those found in two-key chains comprising the same schedule types.

In concurrent chain schedules (Autor, 1960), choice between two mutually exclusive reinforcement schedules (terminal links) is assessed by measuring response rates to concurrently arranged variable-interval (VI) schedules (initial links) that allow access to the terminal links. Extensive data are now available on choice between various pairs of schedules in the terminal links, but there is only one report (Reynolds, 1963) of performance in a three-way choice (three concurrent initial links and three mutually exclusive terminal links). In Reynolds' experiment, the initial links were equal VI schedules with a mean interval of 90-sec (VI 90-sec). In each mutually exclusive terminal link, the animals were exposed to either 30 sec of blackout or to a schedule that required 25 responses to produce 3-sec reinforcement. These outcomes occurred in each terminal link with a specified probability. When either the 30-sec blackout had elapsed, or the animal had obtained reinforcement, the conditions reverted to the three concurrent initial links. Reynolds found that the relative rates of responding (responses on a key divided by total responses) in the initial links matched the relative rates of occurrence of reinforcement

obtained in the terminal links (probability of reinforcement on one key divided by the sums of the probabilities). Thus, if the probability of blackout on the three keys was 0.25, 0.50, and 0.75, respectively, the relative rates of responding in the initial links were 0.50, 0.33, and 0.17 respectively if the terminal links were entered equally often. If the terminal links were entered unequally, the animals matched relative initial-link responses to relative obtained terminal-link reinforcement frequencies. In control conditions, Reynolds showed that the same relation held when only two chains were available.

The procedure of concurrent chain scheduling used by Reynolds (1963), involving a certain probability of blackouts in the terminal links, is unique in the literature. The more usual procedure is for no blackouts to be arranged and for choice to be manipulated by changing the parameters of the terminal-link schedules. The first part of the present experiment was designed as a systematic replication of Reynolds' (1963) experiment using the more conventional procedure. The terminal-link schedules were fixed-interval (FI) schedules, which have already been the subject of extensive research as the terminal links of two-key concurrent chains schedules (Duncan and Fantino, 1970; Killeen, 1970; Davison and Temple, 1973; Wardlaw and Davison, 1974). In the first part of this experiment, all three initial links were variable-interval schedules with a mean interval of 60 sec (VI 60-sec). The terminal-link FI schedules on keys 2 and 3 were always

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FI 25-sec and FI 15-sec respectively, while that on key 1 was varied between 5 and 40 sec in the various experimental conditions. In the second part of this experiment, the three terminal-link schedules were FI 5-sec, FI 25-sec, and FI 15-sec respectively. The initial-link VI schedule on key 1 was varied, while those on keys 2 and 3 were kept at VI 60-sec.

METHOD

Subjects

Six homing pigeons, previously trained on multiple schedules in similar equipment, were maintained at $80\% \pm 15$ g of their free-feeding body weights. Bird 142 died during the second part of the experiment, and these data were not reported in this part.

Apparatus

The experimental chamber, which was situated remote from solid-state control equipment, contained three response keys 2 cm in diameter, 9.5 cm apart, and 22.5 cm from the grid floor. Each key was operated by a peck exceeding approximately 0.1 N. The chamber was sound-attenuated, and some masking noise was provided by an exhaust fan. Two sources of feedback were arranged for pecks on illuminated keys: a 30-msec offset of the keylight and the click of a relay situated behind the keys. Pecks on keys that were not illuminated had no consequences. A grain hopper was situated below the center key and 10 cm from the floor. During reinforcement, the hopper was illuminated and the keys were darkened. No other source of illumination was provided.

Procedure

The reinforcer consisted of a nominal 3-sec access to wheat. Sessions were terminated in blackout when a fixed number of reinforcements had been obtained. This number (see Table 1) was 50 or less, and gave a session time of not more than 50 min.

Since all pigeons had previous training on various schedules, no key-peck training was required and the animals were placed directly on the first experimental condition.

When the session began, all three keys were white and a VI schedule was in operation on each. In the first part of the experiment, the VI schedules were all identical and consisted of a randomized sequence of 12 intervals taken

from the progression $a, a + d, a + 2d, \text{etc.}$, with $a = 5$ sec and $d = 10$ sec. A peck on one of the keys in the white initial links produced the terminal link on that key only if the initial-link schedule on that key had completed timing an interval. The terminal link on key 1 (the left key) was signalled by that key turning red, which was associated with various FI schedules (Table 1). The terminal links on keys 2 (center) and 3 (right) were green and blue respectively. When a terminal link had been produced on one key, the other two keys blacked out, became inoperative, and the associated initial-link timers stopped timing. After one reinforcement, the white initial links on all three keys were reinstated and the initial-link schedule associated with the terminal link that had just been entered was restarted. The initial-link schedules on the other two keys continued timing, but only if they had not arranged a terminal-link entry. If one or both had arranged an entry, it remained available.

Performance was assumed stable when each animal had reached a defined criterion five, not necessarily consecutive, times. The criterion was that the median of the relative numbers of responses for each of the three possible two-key initial-link comparisons (pecks on key 1/pecks on keys 1 and 2; key 1/keys 1 and 3; and key 2/keys 2 and 3) in the last five sessions did not differ by more than 0.05 from the median of the five sessions before these. When all animals had met this criterion five times for each initial-link comparison, the experimental parameters were changed for all animals as a group.

The independent variable in the first part of the experiment was the duration of the terminal-link FI schedule on key 1, which was varied in an irregular sequence from 5 to 40 sec. In the second part, the terminal links were FI 5-sec, FI 25-sec, and FI 15-sec respectively, and the initial link on key 1 was varied from VI 30-sec to VI 180-sec. The intervals comprising these schedules were randomized from the same arithmetic progression. The values of a and d were, respectively: VI 30-sec, 2.5 and 5 sec; VI 90-sec, 7.5 and 15 sec; VI 120-sec, 10 and 20 sec; and VI 180-sec, 15 and 30 sec. The initial links on keys 2 and 3 were VI 60-sec at all times.

In all conditions, the number of responses on the three keys in the initial and terminal

Table 1

Sequence of experimental conditions, number of sessions training, response rates on each key in the initial and terminal links, and the average number of reinforcements per session obtained in each terminal link. The data are averaged over the last five sessions of each condition. Schedules are specified in seconds.

Independent Variable	Sessions	Initial-Link Response Rates			Terminal-Link Response Rates			Terminal-Link Reinforcements		
		Key 1	Key 2	Key 3	Key 1	Key 2	Key 3	Key 1	Key 2	Key 3
Part One: All initial links VI 60-sec, independent variable is the FI terminal-link schedule on Key 1										
Absent	29	—	4.70	13.47	—	54.82	57.14	—	20.23	24.77
20	33	9.20	1.38	8.10	56.73	48.69	52.56	19.87	11.13	19.00
30	40	3.29	1.74	15.93	48.86	61.27	63.12	16.83	12.43	20.74
15	35	10.22	0.77	6.79	61.05	39.36	44.52	20.77	8.87	20.37
25	30	3.87	1.49	15.58	47.74	44.93	51.96	18.20	12.13	19.73
10	26	14.00	0.64	6.01	80.18	38.16	53.07	21.63	8.67	19.70
40	35	2.16	1.61	16.64	38.79	51.36	53.69	14.63	12.73	19.23
5	33	22.84	0.31	3.46	114.86	39.64	58.69	24.97	5.60	19.43
Part Two: Terminal links are FI 5-sec, FI 25-sec, and FI 15-sec, independent variable is the initial-link VI schedule on Key 1										
120	32	14.34	0.71	5.37	121.22	53.81	65.32	11.72	6.20	17.76
180	23	8.56	1.04	8.18	122.19	38.09	47.87	8.76	8.04	22.68
30	29	41.21	0.17	0.76	109.89	27.92	92.05	40.60	1.96	7.04
90	22	21.78	0.42	4.17	113.97	57.80	77.90	18.72	5.24	17.16

links, and the number of entries into each terminal link, were recorded.

RESULTS

The mean response rates² in the initial and terminal links and the mean number of reinforcements obtained, averaged over the final five sessions of each experimental condition and over the group of animals, are shown in Table 1. In order to conserve space, the present results and discussion use only these group average data. Also shown in this Table are the numbers of sessions required to reach stability in each condition.

Part One

The absolute response rates in the three initial links in the first part of the experiment are shown in Figure 1 as a function of the duration of the FI schedule arranged in the terminal link on key 1. Lengthening the terminal-link schedule on key 1 reduced initial-link response rates on this key, and increased initial-link rates on the other two keys. The initial-link response rates on keys 2 and 3 were

considerably higher when the chain on key 1 was absent, as was also found by Reynolds (1963). In comparing the response rates on the three keys, the rate on key 2 was lower than would be expected from the key 1 data. When the terminal link on key 1 was FI 25-sec (as was arranged on key 2), the initial-link rate was about 4.5 per minute. The response rate on key 2 never reached this level in any condition, and we are unable to suggest any reason for this. The key 1 data suggest that an FI 15-sec terminal link would produce an initial-link rate of about 10 responses per minute, which is well within the range of rates found in the initial links on key 3, which had a FI 15-sec terminal-link schedule.

The terminal-link response rates are shown in Figure 2. As the value of the FI schedule in the terminal link on key 1 increased, the response rate decreased. There was, however, no evidence that the response rates in the terminal links on keys 2 and 3 changed systematically, and the terminal-link response rate on key 2 (FI 25-sec) was close to the rate predicted by the function for key 1. This figure also demonstrates that the terminal-link response rates on keys 2 and 3 were relatively unaffected by the presence or absence of the chain on key 1.

²Raw data for each individual animal may be obtained on request from the authors.

The relative rates of responding in the initial links on keys 1 and 2 (responses on key 1/responses on keys 1 and 2) and on keys 1 and 3 are shown in Figure 3 as a function of the relative rates of reinforcement arranged in the terminal links on these keys. The diagonal line is the function that would be obtained if the relative initial-link response rates equalled the relative terminal-link reinforcement rates. Such equality does not describe the present data, relative response rates generally being too low when key 1 provided a lower terminal reinforcement rate, and too high when it provided a larger reinforcement rate. Figure 3 also shows the relative response rate on keys 2 and 3 as a function of the terminal-link schedule on key 1. Little trend in the relative rates is evident when the terminal-link schedule on key 1 is changed in value, although the absence of the chain on key 1 did lead to a large increase in the relative rate to key 2.

Fig. 1. Absolute response rates per minute in the initial links on the three keys when the terminal-link schedule on key 1 was varied. The continuous lines show the rates predicted from Equations 3a to 3c. Also shown are the initial-link response rates on keys 2 and 3 when the chain on key 1 was absent.

The lack of matching of relative response and terminal-link reinforcement rates in Figure 3 could simply be due to the control of the animals' performance by the obtained reinforcement rates, rather than by the arranged rates (Reynolds, 1963). Table 1 shows that the animals did not enter each terminal link equally often, and thus arranged rates are different from obtained rates. To investigate this possibility, arranged terminal-link reinforcement rates were multiplied by the number of times the animal was exposed to that reinforcement rate, and relative obtained reinforcement rates obtained. All relative initial-link response data are shown as a function of these predictions in Figure 4. Again, there was no evidence of an equality between relative initial-link response rates and relative obtained terminal-link reinforcement rates. This figure does appear to make the present data more internally consistent, the data from all three two-key comparisons, as well as those from the two-key condition, fitting roughly on an ogival function.

Part Two

The data for Part Two include one set from Part One, from the condition when the schedule on key 1 was chain VI 60-sec FI 5-sec.

Fig. 2. Absolute response rates per minute in the terminal links on the three keys when the terminal-link schedule on key 1 was varied. The continuous line in the upper graph is the rates predicted from Equation 2, while those in the lower graphs show rates of 46 and 53 responses per minute respectively. Also shown are the terminal-link response rates on keys 2 and 3 when the chain on key 1 was absent.

Fig. 3. Upper graph: relative number of initial-link responses ($P_1/P_1 + P_2$, or $P_1/P_1 + P_3$) as a function of the relative arranged rate of reinforcement in the terminal links ($R_1'/R_1' + R_2'$, or $R_1'/R_1' + R_3'$). The main diagonal shows the expected function if relative initial-link response rates equalled relative terminal-link reinforcement rates. Also shown on this graph are the data from the condition in which the chain on key 1 was absent. Lower graph: relative initial-link response rate on keys 2 and 3 ($P_2/P_2 + P_3$) as a function of the value of the FI schedule arranged in the terminal link on key 1. Also shown are the data from the condition in which the chain on key 1 was absent.

When the terminal links on the three keys were FI 5-sec, FI 25-sec, and FI 15-sec, and the initial link on key 1 was varied, the initial-link response rate on key 1 fell as the mean interval was increased (Figure 5). At the same time, the initial-link response rates on the other two keys (both VI 60-sec schedules) increased. Under these conditions, there was no systematic change in the terminal-link response rates on any of the keys, although the variance in these data was quite large (Figure 6).

DISCUSSION

Figures 3 and 4 showed that pigeons do not match relative initial-link response rates to

Fig. 4. The relative number of initial-link responses on the three pairs of keys as a function of the relative obtained rate of reinforcement on each pair. Obtained rates were calculated as, for example, $R_1'E_1/R_1'E_1 + R_2'E_2$, where E_1 and E_2 are the numbers of times the animals entered the two terminal links. See Figure 3.

Fig. 5. Absolute response rates per minute in the initial links on the three keys when the initial-link schedule on key 1 was varied. The continuous line shows the rates predicted from Equations 6a to 6c.

either arranged or obtained relative terminal-link reinforcement rates. Thus, either the procedure of terminal-link scheduling, or the types of terminal-link schedules, led to the difference between these and Reynolds' (1963) results. This is not surprising, since such matching has been reported only for terminal-link VI schedules (Herrnstein, 1964), while many other different terminal schedule combinations have been investigated.

Fig. 6. Absolute response rates per minute in the terminal links on the three keys when the initial-link schedule on key 1 was varied. The continuous lines show rates of 116, 43, and 68 responses per minute respectively.

Wardlaw and Davison (1974) analyzed a two-key concurrent chain experiment in which the initial links were VI schedules and the terminal links FI schedules. The analysis was based upon Davison's (1974) analysis of chained schedules, and upon previously reported analyses of multiple schedules (Lander and Irwin, 1968; Barron and Davison, 1972). The two chains comprising the concurrent chain schedules were separately analyzed, and responding in the FI terminal links was analyzed as a multiple schedule in which the two components were spaced in time by the occurrence of the initial links. An analysis of the same type was carried out on the present data. The response rates in single schedule components, or the ratio of response rates in pairs of schedules, are shown to be relatively simple functions of obtained reinforcement rates, or ratios of obtained reinforcement rates. From these functions are developed extensions to predict relative response rates in the initial links.

Part One

First, each of the three chained schedules was analyzed separately. In the following, the subscripts 1, 2, and 3 refer to the keys, and unprimed and primed variables refer to the initial and terminal links respectively. The chain analysis consists of showing the relation between the ratio of response rates in the initial and terminal links as a function of the ratio of reinforcement rates in these links. The reinforcement rates were obtained by assuming that some reinforcement is given when the animal enters the terminal link, and

Fig. 7. Response rates in the initial links as a ratio of response rates in the terminal links for the chains on each key as a function of the ratio of reinforcement rates in the initial and terminal links. Initial-link reinforcement rates were taken as the time in seconds scheduled in the initial links divided into 60. Both co-ordinates are logarithmic. The straight lines were fitted by the method of least squares to the logarithmic data. Next to each line is shown the equation of the best-fitting straight line in logarithmic terms.

thus the initial-link reinforcement rate per minute is simply the time in seconds arranged for the initial link divided into 60. The chains on keys 2 and 3 are constant; thus, the initial-to terminal-link response ratios for these keys are shown as a function of the ratio of initial-to terminal-link reinforcement rates on key 1. These functions are shown in Figure 7 on double-logarithmic coordinates (Davison, 1974; Wardlaw and Davison, 1974).

The logarithmic data are a reasonable fit to the straight lines, which were obtained by the

method of least squares. Figure 7 shows, first, that when the terminal link on key 1 was increased, the ratio of initial- to terminal-link response rates on this key fell. But for keys 2 and 3, increasing the terminal link on key 1 increased the initial- to terminal-link response rate ratios. As would be expected, the fitted line for key 1 crossed the function for key 3 (FI 15-sec terminal link) when the terminal link on key 1 was about 15 sec. However, the function for key 2 did not cross that for key 1 within the range of key 1 terminal links investigated. This reflects the already mentioned fact that the initial-link response rates on key 2 were considerably lower than those on the other two keys. In other words, there was a bias towards keys 1 and 3 in initial-link responding, although this bias was not evident in terminal-link responding. Finally, the functions for keys 2 and 3 were approximately parallel, showing that responding on keys 2 and 3 was affected proportionally by changes in the terminal link on key 1. The function for key 2 was displaced below that for key 3 for both the reason mentioned above, and also because the key 2 schedule was chain VI 60-sec FI 25-sec, whereas the key 3 schedule was chain VI 60-sec FI 15-sec.

The functions shown in Figure 7 can be summarized by three equations:

$$P_1/P_1' = 0.052(R_1/R_1')^{-0.65} \quad (1a)$$

$$P_2/P_2' = 0.060(R_1/R_1')^{0.77} \quad (1b)$$

$$P_3/P_3' = 0.47(R_1/R_1')^{0.82} \quad (1c)$$

where P and R refer to response rates and reinforcement rates, primed variables refer to the terminal links, and the subscripts refer to keys 1 to 3. The values of the exponents and constant multipliers in these equations may be compared with those found by Wardlaw and Davison (1974) for a two-key concurrent chain comprising similar schedules. In that experiment, both the exponent and the constant multiplier were a function of initial-link length, and the predicted values for the present experiment are: exponent, -0.85 ; constant, 0.026 . These agree reasonably well with the function for key 1, but not those for the other two keys, which show positive rather than negative signs to the exponents. The differences in sign show that while increasing the reinforcement rate in the terminal-link on key 1 increases the initial- to terminal-link response ratio on that key, it decreases the ratio

on the other two keys. This was not reported by Wardlaw and Davison, but their design may have precluded the clear demonstration of such an effect as they alternated the terminal-link schedules in each successive condition.

The response rates in the terminal links in this part of the experiment are particularly interesting because they show no interaction between responding in these schedules. Figure 2 showed that while the response rate in the terminal link on key 1 varied as a function of the schedule in this link, the response rates in the terminal links on keys 2 and 3 remained constant at about 46 and 53 responses per minute respectively. This result is contrary to previous reports on two-key concurrent chains. Both Hursh and Fantino (1973) and Wardlaw and Davison (1974) showed consistent interactions between terminal-link response rates. For some reason, these may be absent in three-key concurrent chains.

The constancies in response rates in the terminal links on keys 2 and 3 may be used to simplify Equations 1b and 1c. Likewise, Equation 1a may be simplified by fitting a function to the relation between key 1 terminal-link response rates and reinforcement rates. The relation may be summarized as:

$$P_1 = 32(R_1')^{0.51} \quad (2)$$

This equation, which is plotted with the obtained data in Figure 2, is an excellent fit to the data. It also predicts the terminal-link response rates on keys 2 and 3 reasonably accurately as 50 and 65 responses per minute respectively. Equations 1a to 1c may also be further simplified as the initial links on each key were equal to each other and to a reinforcement rate of 1.0 per minute.

Simplifying Equations 1a-1c gives the following equations for initial-link response rates:

$$P_1 = 1.66(R_1')^{1.16} \quad (3a)$$

$$P_2 = 2.76(R_1')^{-0.77} \quad (3b)$$

$$P_3 = 24.9(R_1')^{-0.82} \quad (3c)$$

These functions are plotted in Figure 1 for comparison with the data. The fits are generally quite good. These equations bring out the strong rate-increasing effect on key 1 initial-link responding of increasing the terminal-link reinforcement rate on key 1, and the strong rate-decreasing (inhibitory) effect of this change on responding in the other initial links.

From Equations 3a to 3c, predictions may be made of the relative initial-link response rates in the three-key conditions of Part 1 of this experiment. Calculations of the data shown in Figure 3 showed that the mean deviation of the data from the predictions was 3.9%, which compares favorably with the fits reported by Hursh and Fantino (1973).

While, as noted above, the response rates on keys 2 and 3 remained constant when the terminal-link reinforcement rate on key 1 was varied, the total terminal-link output changed in the following way with changes in the total terminal-link reinforcement rate:

$$(P_1' + P_2' + P_3') = 94(R_1' + R_2' + R_3')^{0.23}.$$

This relation was obtained in the usual way by fitting a straight line to the relation between the logarithm of the sum of response rates and the logarithm of the sum of the reinforcement rates. The relation is similar to that reported for two-key concurrent schedules (Catania, 1963) and for multiple schedules (Lander and Irwin, 1968). However, Wardlaw and Davison (1974) did not find the same relation for two-key concurrent chains, and they also found no relation between total initial-link output and total terminal-link reinforcement rates. The present results support this latter finding. The total initial-link output is approximately 21 responses per minute overall, although the rates on each individual initial link varied strongly from condition to condition (Figure 1).

Part Two

The data from Part Two were analyzed according to the same general procedure as used with Part One. It was first noted that, although the terminal-link response rates (Figure 6) were quite variable, they showed no clear trend. Accordingly, they were taken as constant. The rates, with the rates predicted from Equation 2 in parentheses, are respectively: 116 (114), 43 (50), and 68 (65) responses per minute. Thus, Equation 2 is a reliable predictor of terminal-link rate in both parts of this experiment. It further follows that the total terminal-link output ($P_1' + P_2' + P_3'$) is constant at about 227 responses per minute.

The total output in the initial links varied strongly with initial-link length on key 1, according to the equation:

$$P_1 + P_2 + P_3 = 6(R_1 + R_2 + R_3)^{1.33}. \quad (5)$$

The fit is good, as the variance in the data is 0.08, and the variance between the data and the predictions of Equation 5 is 0.005. The exponent is much larger than is usually reported for total output functions, and we are unable to explain this at present.

In view of the constancies in terminal-link responding shown above, the analysis of initial-link rates moved directly to prediction in terms of initial-link "reinforcement rates" (the initial-link time in seconds divided into 60). The three best-fitting relations are:

$$P_1 = 24(R_1)^{0.83} \quad (6a)$$

$$P_2 = 0.32(R_1)^{-1.04} \quad (6b)$$

$$P_3 = 2.34(R_1)^{-1.27} \quad (6c)$$

and they are plotted in Figure 5 for comparison with the obtained data. The fits were again quite satisfactory. These equations show that the initial-link response rate on key 1 was a direct function of the initial-link reinforcement rate. On the other two keys, the relations were both similar inverse or inhibitory interactions. Comparing Equations 6a to 6c with Equations 3a to 3c, it can be seen that the direct rate-increasing effect on key 1 initial-link responding was somewhat larger with increases in initial-link reinforcement rate than with increases in terminal-link reinforcement rate. The rate-decreasing effects of such a change on key 1 on initial-link responding on keys 2 and 3 were also greater with increases in initial-link reinforcement rate.

Collation of Results

We have reported a series of equations that specify both rate-increasing and rate-decreasing effects of varying both the terminal and the initial link on one key of a three-key concurrent chains schedule. From these equations it should be possible to derive a single equation that summarizes the results of both parts of the experiment, *i.e.*, is true for both sets of data.

For key 1, an equation that is true for both parts of this experiment may be derived from Equations 1a and 6a. It is:

$$P_1/P_1' = 0.052(R_1)^{0.83}(R_1')^{0.65}. \quad (8)$$

Equation 2 gives the value of P_1' for each R_1' , and thus Equation 8 simplifies to:

$$P_1 = 1.66(R_1)^{0.83}(R_1')^{1.16}. \quad (9)$$

This equation is appropriate only for predicting the initial-link response rate on key 1 when the schedules on keys 2 and 3 are constant. As such, it can be used to predict the data from both parts of the experiment when used in conjunction with Equations 3b, 3c, 6b, and 6c. Calculations show that it predicts the present initial-link relative response rates with a mean deviation (Hursh and Fantino, 1973) of 3.9%.

It is beyond the scope of this paper to do more than indicate the sort of equation that would be expected if all initial- and terminal-link schedules were varied in an experiment. The analysis would proceed by noting that the multiplier in Equation 9, 1.66, is composed of inhibitory effects of the initial- and terminal-link schedules on keys 2 and 3, *i.e.*,

$$P_1 = (R_1)^{0.89}(R_1')^{1.16}(R_2)^{-w}(R_2')^{-x}(R_3)^{-y}(R_3')^{-z}$$

and the function for the other two keys should be similar. The present experiment unfortunately does not give sufficient information as to the values of the inhibitory exponents, although we could assume that initial-link inhibitory interactions might have an exponent of about -1.1, while terminal-link interactions might give an exponent of about -0.8.

In conclusion, we have, like Wardlaw and Davison (1974), found lawful relations within the components comprising a concurrent chain schedule. But the relations in the present three-key procedure were not identical with those occurring in a two-key concurrent chain comprising the same types of schedules. As Wardlaw and Davison noted, it is now important to discover some method of predicting the parameters of the equations to these relations. It is also necessary to investigate whether this type of analysis is useful with data from concurrent chains comprising other component schedules.

REFERENCES

- Autor, S. M. *The strength of conditioned reinforcers as a function of the frequency and probability of reinforcement*. Unpublished doctoral dissertation, Harvard University, 1960. Reprinted in D. P. Hendry (Ed.), *Conditioned reinforcement*. Homewood, Illinois: The Dorsey Press, 1969. Pp. 127-162.
- Barron, B. and Davison, M. C. Performance in multiple fixed-interval schedules. *Journal of the Experimental Analysis of Behavior*, 1972, 17, 375-379.
- Catania, A. C. Concurrent performances: reinforcement interaction and response independence. *Journal of the Experimental Analysis of Behavior*, 1963, 6, 253-263.
- Davison, M. C. A functional analysis of chained fixed-interval schedule performance. *Journal of the Experimental Analysis of Behavior*, 1974, 21, 323-330.
- Davison, M. C. and Temple, W. Preference for fixed-interval schedules: an alternative model. *Journal of the Experimental Analysis of Behavior*, 1973, 20, 393-403.
- Duncan, B. and Fantino, E. Choice for periodic schedules of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1970, 14, 73-86.
- Herrnstein, R. J. Secondary reinforcement and rate of primary reinforcement. *Journal of the Experimental Analysis of Behavior*, 1964, 7, 27-36.
- Hursh, S. R. and Fantino, E. Relative delay of reinforcement and choice. *Journal of the Experimental Analysis of Behavior*, 1973, 19, 437-450.
- Killeen, P. Preference for fixed-interval schedules of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1970, 14, 127-131.
- Lander, D. G. and Irwin, R. J. Multiple schedules: effects of the distribution of reinforcements between components on the distribution of responses between components. *Journal of the Experimental Analysis of Behavior*, 1968, 11, 517-524.
- Reynolds, G. S. On some determinants of choice in pigeons. *Journal of the Experimental Analysis of Behavior*, 1963, 6, 53-59.
- Wardlaw, G. R. and Davison, M. C. Preference for fixed-interval schedules: effects of initial-link length. *Journal of the Experimental Analysis of Behavior*, 1974, 21, 331-340.

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