INVERSE RELATION BETWEEN CHOICE AND LOCAL RESPONSE RATE WITH A SCHEDULE OF RESPONSE-PRODUCED BLACKOUTS¹

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Pigeons were exposed to a two-key concurrent chains schedule in which identical frequencies and distributions of food presentations generated different response rates in the terminal links. An inverse relation between local rate of response in the terminal links and relative frequency of response in the initial links was observed. The high response rate was produced in one terminal link by a second-order schedule in which responding produced brief blackouts of the response key. Responding under the same schedule in the other terminal link did not produce blackouts. Under initial training and after spatial reversal of the terminal-link schedules, two of three pigeons had lower relative frequencies of response in the initial member of the chain with the higher terminal link response rate. The third pigeon showed no change in preference at reversal.

Recently, evidence has been presented that indicates, that very different environmental events have similar effects on behavior. It appears that the manner in which an event is scheduled, without regard to the characteristics of the event itself, is a major source of behavioral control. For example, Morse, Mead, and Kelleher (1967) demonstrated that squirrel monkeys would respond to produce electric shock on a fixed-interval (FI) schedule and that the resulting behavior was similar to that produced by FI schedules of food presentation. McKearney (1969) provided additional evidence for the similarity between FI schedules of electric shock and food presentation by demonstrating an inverse relation between FI duration and response rate when squirrel monkeys were exposed to FI schedules of response-produced shock.

Several experiments have compared the behavioral effects of scheduling brief blackouts relative to the effects of scheduling food. Neuringer and Chung (1967) reported that a substantial amount of key pecking was generated in pigeons by an FI schedule in which responding produced either a brief blackout

or food. Food presentations were scheduled on response-initiated FI 5-sec schedules by a variable-interval (VI) schedule. (The initiating response is a fixed-ratio one or FRI.) A response produced a brief blackout at the end of each FI 5-sec period in which food delivery was not scheduled by the VI. Following Kelleher's (1966) terminology, Neuringer and Chung's (1967) schedule may be characterized as a second-order VI 1-min (tandem FR 1 FI 5-sec) schedule with blackouts. That is, responding on a tandem FR 1 FI 5-sec schedule produced food on a VI schedule but if no food was arranged by the VI, responding produced blackouts.

Chung and Neuringer (1967) demonstrated that response-produced blackouts arranged by this VI 1-min (tandem FR 1 FI 5-sec) schedule appear to function in the same manner as food presentations. That is, when response-initiated FI schedules in which all intervals terminated with food presentation were compared to response-initiated FI schedules in which the intervals ended with either food or blackout, response rates were equal (Chung and Neuringer, 1967). Neuringer (1968) suggested that this finding indicates that a schedule exerts more control over response rate than frequency or probability of food presentation.

In addition to controlling rate of responding, schedules of reinforcement also control choice. One choice procedure that has been employed frequently is the concurrent chains

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schedule of reinforcement (Herrnstein, 1964). The concurrent chains procedure involves two initial-link schedules that are concurrently available to an organism. Reinforcement of responding in the initial links is by access to a schedule arranged as the terminal link of one of the chains. Once food has been obtained on the schedule in a given terminal link, the concurrent initial links of the chains are made available to the animal again. The proportion of total initial-link responses emitted on one operandum is the measure of choice of the terminal links.

Recently, evidence has been presented that indicates that relative frequency of response is influenced by the types of reinforcement schedules employed in the terminal links of the concurrent chains and by the rates of response that these terminal-link schedules generate. For example, Fantino (1968) demonstrated that when equal rates of food presentation were scheduled in the terminal links, pigeons evidenced a higher initial-link relative frequency of response for a FI schedule than for a schedule in which a high rate of response was required for reinforcement. In a related experiment, Schuster (1969) exposed pigeons to a discrete-trials concurrent chains schedule in which the only difference between the two terminal links was that in one responding on an FR 11 schedule produced a 0.7-sec stimulus that was paired with food presentation on a VI 30-sec schedule, while the consequence of responding in the other terminal link was the presentation of food on a VI 30-sec schedule. Schuster (1969) reported low initial-link relative frequencies of response for the terminal link schedule arranging the extra stimulus even though relative rates of response in this terminal link were higher than in the other. These data appear to replicate the inverse relation between choice and response rate reported by Fantino (1968), but strict comparisons are difficult because Schuster (1969) did not report his terminal-link data in terms of responses per unit of time.

Fantino's (1968) and Schuster's (1969) results are relevant to the analyses of reinforcement schedules given by Morse, Mead, and Kelleher (1967), McKearney (1969), and Neuringer (1968). That is, since response rates generated by FI schedules of blackouts or electric shock are comparable to those generated by FI schedules of food presentation, it might be expected

that animals would also choose indifferently between FI schedules of food presentation and FI schedules of blackouts or electric shock. However, the results of Fantino's (1968) and Schuster's (1969) experiments indicate that there is no necessary covariance between choice in the initial links of concurrent chains and response rates in the respective terminal links.

The present experiment investigated rate of response and choice as they relate to the preceding accounts of behavior controlled by reinforcement schedules. This was accomplished by employing Neuringer and Chung's (1967) reinforcement schedule in one of two concurrent chains. The initial links of these chains were identical concurrent VI schedules, and rates of food presentation were equal in both terminal links. The only difference between the two terminal links was that one was a second-order schedule that intermittently scheduled response-contingent blackouts and the other scheduled no blackouts. If response rate and relative frequency of response are unitary measures of behavior generated by schedules of reinforcement, they should covary in this experiment. Animals exposed to the concurrent chains should choose the second-order schedule that arranges blackouts if that schedule enhances response rate as reported by Neuringer and Chung (1967).

METHOD

Subjects

Three White Carneaux pigeons were maintained at approximately 80% of their free-feeding body weights and were housed individually in cages where water was continuously available. These pigeons had extensive exposure to a concurrent VI 1-min VI 3-min schedule with a changeover key (Findley, 1958) six months before being used in this experiment.

Apparatus

The experimental chamber was a 12 by 14 by 13 in. (30 by 35 by 33 cm) sound-attenuating enclosure that contained two translucent plastic discs 0.75 in. (2 cm) in diameter and separated from each other by a distance of 4 in. (10 cm). The response keys required a force of 15 g (0.15 N) to be operated. Centered below the response keys was a

solenoid-operated hopper that presented mixed grain for 4 sec. The response keys were transilluminated with various colors during different parts of an experimental session. Keylights were extinguished during hopper presentations. Standard electromechanical relay equipment and electrical impulse counters were used to control the experimental conditions and to record data. The interreinforcement intervals in all variable-interval schedules used in this experiment were arranged in the following arithmetic distribution: 110, 90, 40, 60, 0, 20, 120, 70, 100, 80, 10, 50, and 30 sec.

Procedure

A concurrent chains schedule of reinforcement (Herrnstein, 1964) was used in which the reinforcement schedule described by Neuringer and Chung (1967) was the terminal link of one of the concurrent chains. Concurrent chains consist of two simple chain schedules where the links more removed from food presentation are concurrent. In the present experiment, these initial links were two VI 1-min schedules that operated simultaneously and independently. Both response keys were transilluminated with white lights during the initial link. When an interreinforcement interval elapsed in one of the VI schedules, a response on its associated key gained access to the terminal link of the chain scheduled on that key. When access to the terminal link was gained: (1) the key color changed to red (on the left key) or green (on the right key); (2) the remaining keylight was darkened; and, (3) the initial-link VI tape pullers stopped. Once one response-produced food presentation occurred in either terminal link, the initial-link schedules were reinstated. A changeover delay was not used in this experiment. Sessions were terminated after 60 food presentations.

The reinforcement schedule described by Neuringer and Chung (1967) made up the terminal link associated with the left response key. That is, at the end of a response-initiated FI 5-sec period, a response produced food if an interreinforcement interval had elapsed on a VI 1-min schedule. If an interreinforcement interval had not elapsed, a response at the end of 5 sec produced a 1-sec blackout of the response key. The VI tape puller continued to function during blackouts. Food was presented only at the end of the FI periods. Thus, as-

sociated with the terminal link of the chain on the left response key was a second-order schedule in which the response terminating a tandem FR 1 FI 5-sec schedule produced either food under a VI 1-min schedule or a 1-sec blackout when food was not available on the VI schedule.

The terminal link of the right-key chain schedule was identical to the left key, except that no blackouts occurred. The second-order schedule was in effect such that food could be produced by a response only at the end of a FI 5-sec period. When no food presentation was due, the FI 5-sec schedule recycled with a response.

All pigeons were exposed to this concurrent chains schedule until the range of the relative frequency of response in the initial links was not greater than 0.10 for 10 consecutive sessions. Relative frequency of response is the proportion of the total initial-link responses emitted on a particular response key. One stability was evident in this measure, the second-order schedule that arranged response-contingent blackouts was switched to the terminal link of the chain schedule associated with the right response key. The numbers of sessions during which blackouts were scheduled on the left and right keys, respectively, for each subject were the following: for # 826, 41 and 70; for # 4183, 32 and 84; and for # 5265, 33 and 69.

RESULTS

Since the emphasis of this experiment was on a comparison between rate of response and choice generated by a schedule of response-produced blackouts, data analysis will involve presentation of the relative frequencies of response in the initial links of the concurrent chains and the local rates of response in the terminal links. Relative frequency is the choice measure, and local rate is the rate measure. Local rate of response is the number of responses in a particular terminal link of the concurrent chains divided by the time spent in that link.

Figure 1 presents the relative frequency of response in the left initial link of the concurrent chains for all three pigeons. The left panel of the figure shows the data from Phase 1 of this experiment when the second-order schedule that intermittently arranged

Fig. 1. Relative frequency of responding on the left response key during the initial link as a function of number of sessions.

response-contingent blackouts was associated with the left terminal link. These are the complete data from Phase 1. Two of the three pigeons showed a very low relative frequency of response on the initial-link key associated with the response-produced blackouts while the relative frequency measure for Pigeon 5265 remained near 0.50 during Phase 1.

The right panel of Figure 1 shows the relative frequency of response during Phase 2 when the second-order schedule arranging response-contingent blackouts was changed to the right terminal link. After approximately 20 sessions, relative frequency of response began to shift toward the left response key for Pigeons 4983 and 826 and was very high after

70 sessions. A gradually declining relative frequency of response was evident for Pigeon 4983 for the remainder of this experiment. The relative frequency of response measure for Pigeon 5265 remained near 0.50 during Phase 2.

The relative frequency of response data indicates that initial-link response rates were highest on the key not associated with blackout stimuli in the terminal link. Table 1 presents the absolute rates of responding on each initial-link key for the last five sessions of each condition. These rates were computed as follows: (1) the number of responses on each initial-link response-key was divided by the total time spent in the initial links and, (2) the median of the absolute rates in each experimental condition was then computed. These data support the finding reported for relative frequency of response in the initial links. Table 1 also presents obtained relative frequencies of food presentation in the terminal links during the last five sessions of each

procedure. These were calculated by dividing the number of food presentations occurring in one terminal link by the total and taking the medians. These data indicate that extreme relative frequencies of response in the initial links did not produce great differences in the obtained relative frequency of food presentation in the terminal links.

Figure 2 is a summary graph of the local rates of response in the two terminal links of the concurrent chains schedule. These data are representative of the terminal-link response rates throughout this experiment. The left panel of each portion of this figure represents the last 10 sessions of exposure to the concurrent chains during Phase 1 when the blackouts were associated with the left response key. All three pigeons evidenced the highest response rates on the response key where the blackouts occurred.

The right panel of each portion of Figure 2 shows the local response rates during the last 10 sessions of Phase 2 when the response-

Fig. 2. Local rates of response in the terminal links of the concurrent chains. These data are from the last 10 sessions of each condition of the experiment. Closed circles represent responding on the left response key, and open circles represent responding on the right key.

Table 1

Initial-link absolute rates of responding and terminal-link obtained relative frequencies of food presentation.

<i>Bird Number</i>	<i>Terminal Link Arranging Blackouts</i>	<i>Absolute Response Rate in Initial Links (per sec)</i>		<i>Relative Frequency of Food Presentation in Left Terminal Link</i>
		<i>Left</i>	<i>Right</i>	
826	Left	0.04	0.71	0.45
	Right	0.52	0.04	0.62
4983	Left	0.13	0.75	0.48
	Right	0.34	0.28	0.52
5265	Left	0.29	0.34	0.52
	Right	0.26	0.20	0.50

produced blackouts were associated with the right terminal link. Pigeons 826 and 4983 exhibited marked shifts in response rates when the second-order schedule arranging response-contingent blackouts was changed from the left to the right response key. Local rates of response in the terminal link associated with the response-produced blackouts were quite high, and response rates in the left terminal link declined when the schedule that arranged blackouts was associated with the right response key. Figure 2 also indicates that local response rates in the terminal link in which response-produced blackouts were obtained were declining during the last 10 sessions of the second phase. Pigeon 5265 evidenced a decline in response rate in both terminal links during the last 10 sessions of this experiment.

DISCUSSION

The inverse relationship observed in this experiment between relative frequency of response in the initial links of a concurrent chains schedule and response rate in the terminal links has particular implications for current analyses of the factors controlling choice in concurrent chains schedules and response rate in simple schedules. Herrnstein (1964) reported that animals will show equal relative frequencies of response in the initial links of concurrent chains if the obtained frequencies of food presentation in the two terminal links are identical. In the present experiment, obtained relative frequencies of food presentation were approximately equal in the terminal links, but two of three pigeons evidenced a lower relative frequency of response

in the initial links for the terminal link in which response-contingent blackouts were produced in addition to food than for the terminal link in which only food was obtained. The terminal-link local rates of response were also influenced by response-produced blackouts. That is, higher local rates occurred in the terminal link in which responses intermittently produced blackouts. In this respect, these data are similar to those reported by McKearney (1969), Morse, Mead, and Kelleher (1967), and Neuringer (1968) for simple FI schedules. Thus, the results of this experiment indicate (1) that relative frequency of response in the initial links of a concurrent chains schedule is not simply a function of the scheduling of food in the terminal links; and, (2) that the finding that responding on FI schedule can be maintained by the occurrence of events as disparate as food, electric shock, and blackouts does not mean that identical scheduling of these events will have unitary effects upon choice.

The results obtained from two pigeons in this experiment replicate Fantino's (1968) finding that relative frequency of response in the initial links of a concurrent chains schedule and local rates of response in the terminal links do not necessarily covary. That is, an animal may evidence a high response rate in a schedule that is chosen infrequently. One difference between Fantino's (1968) experiment and this investigation is that Fantino required particular response rates in one terminal link of the concurrent chains schedule. If the pigeon did not meet the response rate contingency, food presentation was delayed. In this experiment, no rate contingency was present in the terminal links of the concurrent

chains schedule, but the pigeons evidenced a high local rate of response in the terminal link where response-contingent blackouts were scheduled even though it was chosen infrequently. Thus, these results extend Fantino's (1968) findings to situations not having a response rate requirement.

Schneider (1968) reported an experiment in which the relative frequency of response in the initial links of concurrent chains was controlled by the presentation of response-contingent blackouts in a terminal link only to the extent that the blackouts affected the rate of food presentation. For example, pigeons responded with equal initial-link relative frequencies when a VI 1-min and a VI 30-sec schedule, in which 50% of the total reinforcements were food presentations and 50% were blackouts, were the schedules in the respective terminal links of the concurrent chains. Since these two schedules arrange equal rates of food presentation, Schneider (1968) concluded that the response-produced blackouts had no effect upon choice. In the present experiment, adding response-contingent blackout stimuli to one terminal link of a concurrent chain had a marked effect upon choice, for the blackouts constituted the only difference between the two terminal links.

Whereas Schneider's (1968) procedure involved replacing a certain percentage of food presentations by response-contingent blackouts, the procedure employed in the present experiment involved superimposing response-contingent blackouts upon a schedule of food presentation. These two procedures arrange quite different numbers of blackouts during an experimental session. The maximum number of blackouts per session occurring in Schneider's (1968) experiment was 50, but in the present experiment a pigeon produced approximately 150 blackouts per session. This is possibly an important variable in the effect of response-produced blackouts upon choice.

The relative frequency of response data from Pigeon 5265 indicate that this pigeon was insensitive to any of the manipulations of this experiment. The cause of this insensitivity is not known.

One interesting aspect of the local response rate data from the last 10 sessions of this experiment is that local rates of response in the

terminal link associated with the blackout stimuli were declining. Also, Pigeon 4983 evidenced an increase in relative frequency of response in the initial link of the concurrent chain that contained response-produced blackouts. Pigeon 826 was not exposed to the schedule arranging blackout stimuli as long as Pigeon 4983, and therefore it is difficult to assess the importance of this change in relative frequency of response after extended exposure to the schedule. The data indicate that the effects of the reinforcement schedule described by Neuringer and Chung (1967) may in time adapt out with extended exposure to the schedule.

REFERENCES

- Chung, S. H. and Neuringer, A. J. Control of responding by a percentage reinforcement schedule. *Psychonomic Science*, 1967, 8, 25-26.
- Fantino, E. Effects of required rates of responding upon choice. *Journal of the Experimental Analysis of Behavior*, 1968, 11, 15-22.
- Findley, J. D. Preference and switching under concurrent scheduling. *Journal of the Experimental Analysis of Behavior*, 1958, 1, 123-144.
- Herrnstein, R. J. Secondary reinforcement and rate of primary reinforcement. *Journal of the Experimental Analysis of Behavior*, 1964, 7, 27-36.
- Kelleher, R. T. Conditioned reinforcement in second-order schedules. *Journal of the Experimental Analysis of Behavior*, 1966, 9, 475-485.
- McKearney, J. W. Fixed-interval schedules of electric shock presentation: extinction and recovery of performance under different shock intensities and fixed-interval durations. *Journal of the Experimental Analysis of Behavior*, 1969, 12, 301-313.
- Morse, W. H., Mead, R. N., and Kelleher, R. T. Modulation of elicited behavior by a fixed-interval schedule of electric shock presentation. *Science*, 1967, 157, 215-217.
- Neuringer, A. J. Varying reinforcement frequency on a percentage reinforcement schedule. *Psychonomic Science*, 1968, 11, 163-164.
- Neuringer, A. J. and Chung, S. H. Quasi-reinforcement: Control of responding by a percentage reinforcement schedule. *Journal of the Experimental Analysis of Behavior*, 1967, 10, 45-54.
- Schneider, J. W. Effects of percentage reinforcement on choice in a concurrent chain schedule. *Psychonomic Science*, 1968, 12, 211-212.
- Schuster, R. H. A functional analysis of conditioned reinforcement. In D. P. Hendry (Ed.), *Conditioned reinforcement*. Homewood, Illinois: Dorsey Press, 1969. Pp. 192-234.

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