CONCURRENT FIXED-RATIO AND AVOIDANCE RESPONDING IN THE SQUIRREL MONKEY¹

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Squirrel monkeys maintained concurrent performances appropriate to a fixed-ratio schedule of food reinforcement on one lever and an avoidance schedule on a second lever. The overall rate of responding maintained by either schedule was not systematically affected when the other schedule was discontinued and its lever removed.

Kelleher and Cook (1959) have described the performances of rats and squirrel monkeys on fixed-ratio and avoidance schedules programmed simultaneously for responses on a single lever. These performances were characterized by a relatively low rate of avoidance responding after reinforcement, followed, after a variable pause, by a relatively high rate of fixed-ratio responding. The independence of the fixed-ratio and avoidance components was demonstrated by extinguishing one and then the other of the two components.

The present experiment examines the same schedules programmed concurrently for responses on two separate levers. In both the one-lever and two-lever cases, two different operants are involved: one is maintained by the fixed-ratio schedule, the other by the avoidance schedule. In the one-lever case, however, the two operants are topographically similar. This can lead to problems in data analysis when quantitative measures of the two operants are desirable (e.g., in drug studies), because of the difficulty of separately counting fixed-ratio and avoidance responses. When the two operants are separated topographically, however, on two levers, this problem does not arise.

Schedules programmed for one response and those programmed for two responses also raise a problem of nomenclature, because both generally are referred to by a single term, *concurrent* (Ferster and Skinner, 1957). To avoid confusion, the term *concurrent* is reserved here for the two-response schedules, and the term *con-*

joint for the one-response schedules. The terms are similar in meaning, but the distinction is supported by the Oxford English Dictionary, which includes in its definition of *concurrent*, "going on side by side"; *conjoint* is defined as "united, combined."

METHOD

Subjects

Three squirrel monkeys (*Saimiri sciurea*) were maintained at about 80% of free-feeding body weight. Monkeys 391 and 399 were experimentally naive before concurrent fixed-ratio avoidance training. Monkey 302 had a history of about a year of responding on the conjoint fixed-ratio avoidance schedules described by Kelleher and Cook (1959). Each monkey was trained separately on the fixed-ratio and the avoidance schedules before they were programmed concurrently. About nine months of daily sessions of the concurrent fixed-ratio avoidance schedules preceded the sessions described below. During this time, various drugs were administered orally at intervals of about one week (Cook and Catania, 1964).

Records of conjoint fixed-ratio avoidance responding in other squirrel monkeys (Kelleher and Cook, 1959) were compared with the records obtained from the present experiment.

Apparatus

The experimental chamber included two Lehigh Valley levers, a modified Gerbrands feeder, and a grid floor. The fixed-ratio lever was mounted 7.5 cm above the grid floor. This lever and the feeder cup were located side by side on one wall, about 7.5 cm apart. The

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avoidance lever, 11.5 cm above the grid floor, was centered on the opposite wall. The two walls were about 25 cm apart. Although a monkey could reach both levers at the same time, simultaneous presses were not observed during the experiment. Two relays, each mounted outside the chamber near its lever, were chosen to provide distinctively different feedback clicks for presses on two levers. Both levers were electrically isolated from the walls. Shocks could be delivered to the grid floor and to the walls in which the levers were mounted by a Grason-Stadler shock generator (1 ma setting). Presses on the fixed-ratio lever were ineffective during reinforcement, which consisted of the delivery of a monkey tablet (Riddle, Rednick, Catania, and Tucker *in press*) and the 5-sec illumination of a white pilot lamp above the feeder cup.

Dim general illumination was provided throughout each session by two white lamps mounted outside the chamber on the Plexiglas wall that contained the door of the chamber. The chamber was enclosed within a ventilated, sound-attenuating housing. Water was continuously available.

Procedure

The fixed-ratio and avoidance schedules were programmed either concurrently, on the two levers, or separately, with the lever for the other schedule removed. Presses on the fixed-ratio lever were reinforced according to a fixed-ratio 100 schedule. Presses on the avoidance lever avoided shock according to a modified Sidman avoidance schedule, with response-shock and shock-shock intervals equal to 30 sec (Sidman, 1953). Shocks were terminated by a press on the avoidance lever or at the end of 10 sec, whichever came first.

The sequences of schedules are summarized in Table 1. Each sequence was preceded and followed by a session of drug administration. Daily sessions were terminated after 100 fixed-ratio reinforcements or after 3 hr. When avoidance alone was programmed, session durations were based on the average session durations of the preceding fixed-ratio avoidance sessions.

RESULTS

Figure 1 compares representative single-response (A and B) and two-response (C and D) performances. The single-response perform-

Table 1

Number of daily sessions under each condition for three squirrel monkeys. For Monkeys 391 and 302, a and b indicate two separate sequences programmed on different occasions.

Procedure	391 ^a	Squirrel Monkey	
		302 ^a	391 ^b , 302 ^b , 399
FR AV*	4	4	5
FR alone	5	5	7
FR AV	6	2	7
AV alone	—	6	7
FR AV	—	9	7

*FR—fixed-ratio; AV—avoidance.

ances were obtained with the conjoint fixed-ratio avoidance schedules described by Keller and Cook (1959), except that the food reinforcement consisted of monkey tablets rather than liquid food. The performance in A is characterized by a low rate of avoidance responding after reinforcement (a) followed by a high rate of fixed-ratio responding (b). In a second monkey's performances, in B, fixed-ratio responding began so soon after reinforcement that it is difficult to determine whether the responding early after reinforcement was controlled by the fixed-ratio or by the avoidance schedule.

The similarity between the single-response and two-response performances is evident in the combined records in C and D, which were obtained by cumulating both fixed-ratio and avoidance responses on a single recorder. Again, a low rate of avoidance responding after reinforcement (c) was followed by a high rate of fixed-ratio responding (d). The number of responses between successive reinforcements, however, was variable and greater than 100, because avoidance responses did not contribute to the fixed-ratio count as they did in the single-response case. The separate performances contributing to the combined record consisted of, on the fixed-ratio lever, a pause after reinforcement (e), during which some responses occurred, followed by a high rate of responding (f), and, on the avoidance lever, a relatively constant rate of responding (g). Some curvature is evident between reinforcements in the fixed-ratio record. The rate of avoidance responding occasionally decreased slightly during responding on the fixed-ratio lever, but shocks were not correlated with high rates of fixed-ratio responding.

The higher-rate combined record from a second monkey (D) is similar to the correspond-

Fig. 1. Comparison of single-response (conjoint) and two-response (concurrent) fixed-ratio avoidance performances in the squirrel monkey. In each case, a low-rate (A and C) and a high-rate (B and D) responder is shown. Pips on the response and baseline event records indicate food reinforcement; pips with filled circles on the response records indicate shocks. In the two-response examples, a third recorder cumulated both fixed-ratio and avoidance responses, and all recorders reset to baseline simultaneously. FR—fixed-ratio; AV—avoidance.

ing single-response record (B). The fixed-ratio record shows that some of the curvature within individual ratios in the combined record was produced by fixed-ratio responding. The rate of avoidance responding was relatively constant. Curvature in fixed-ratio records, which indicates that the rate of fixed-ratio responding accelerated between reinforcements, has also been noted by Sidman (1962), in concurrent fixed-ratio avoidance schedules with rhesus monkeys in which the fixed-ratio reinforcement was a period of time out from avoidance, and by Catania (1963b), in concurrent fixed-ratio variable-interval schedules of food reinforcement with pigeons. In the single-response cases (A and B), any curvature that might have been present in the fixed-ratio records is obscured by the avoidance responding.

The average number of changeovers to the avoidance lever during each ratio varied from session to session, over a range from 2 to 4 changeovers per ratio for Monkey 302, from 3 to 5 for Monkey 399, and from 6 to 9 for Monkey 391.

The rates of responding maintained by the concurrent schedules and by each schedule alone are shown in Fig. 2. Although rates of responding varied from one condition to another, most changes depended on a drifting baseline (e.g., the increasing fixed-ratio rate for Monkey 391, sequence a, and the decreasing fixed-ratio rate for Monkey 399). Removing the fixed-ratio schedule produced a decrease in the rate of avoidance responding in two cases and an increase in the other two cases. Only for Monkey 391 (sequence b) was the change in

rate marked. Shock rates were uniformly low across subjects, and no systematic effects of removing the fixed-ratio schedule on shock rate were observed. The data suggest that, at the schedule values studied, the rate of responding maintained by either schedule was not affected by removal of the other schedule.

DISCUSSION

The present findings demonstrate the similarity of conjoint and concurrent programming of fixed-ratio and avoidance schedules. In both cases, two different operants were maintained by their respective schedules. With conjoint schedules, however, the operants were topographically similar, whereas with concurrent schedules the operants were topographically dissimilar. Thus, the concurrent schedules permitted quantitative measurements and revealed properties of performance (*e.g.*, fixed-ratio curvature, avoidance responding during

fixed-ratio runs) that could not be examined with conjoint schedules.

The independence of the rates of responding maintained by the concurrent fixed-ratio and avoidance schedules is comparable to a finding by Stein (cited in Olds, 1962, p. 562). Stein noted, with rats, that the rate of responding on one lever, each press on which stimulated one brain site, was not necessarily affected by introducing a second lever, each press on which stimulated a second brain site. These findings contrast, however, with the results of experiments on concurrent schedules of food reinforcement in the pigeon. With concurrent fixed-ratio variable-interval schedules, for example, the removal of one schedule increased the rate of responding maintained by the second schedule (Catania, 1963b). This increase depended on the decrease in reinforcement produced by removal of the first schedule, and not on the decreased time spent in responding on that schedule (Catania, 1963a).

Fig. 2. Rates of responding during concurrent scheduling (fixed-ratio avoidance) and during scheduling of either fixed-ratio or avoidance alone. Rates are averages over the last three sessions of each condition, except for the second fixed-ratio avoidance condition for Monkey 302, sequence a, which is an average over two sessions. FR—fixed-ratio; AV—avoidance.

These differences may depend on species or schedule parameters. Another possible explanation may be that interactions occur in concurrent schedules only with similar reinforcers for the two operants. In the pigeon experiments, both reinforcers were food. In the present experiment, the two reinforcers were considerably different: food and avoidance of shock. With different but more closely related reinforcers, such as food and water, complex interactions might be expected.

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Received October 7, 1965