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COMPONENT DURATION AND RELATIVE RESPONSE RATES IN MULTIPLE SCHEDULES[1]

JOÃO CLAUDIO TODOROV

UNIVERSIDADE DE SÃO PAULO

Pigeons were trained on a multiple variable-interval 30-sec, variable-interval 90-sec schedule with each component presented alternately for an equal (on the average) duration. This average duration of exposure to each component was varied from 5 to 300 sec. The main concern was with rate of response in the variable-interval 30-sec component relative to rate of response in the variable-interval 90-sec component. In all cases, rate of response was higher in the variable-interval 30 sec component, but the discrepancy in the rate produced by the two schedules tended to be greatest when the duration of component presentation was brief. The mean proportion of responses emitted during the variable-interval 30-sec component (responses in variable-interval 30-sec component divided by total responses) varied from about 0.60 to 0.71, where 0.75 would be expected on the basis of a matching rule, and 0.59 was that obtained by Lander and Irwin (1968). These results are in agreement with data reported by Shimp and Wheatley (1971) from a similar experiment.

Lander and Irwin (1968) suggested that the equation

$$\frac{N_1}{N_2} = \left(\frac{n_1}{n_2}\right)^a \qquad (1)$$

describes the relationship between the number of responses per component and the number of reinforcements per component in concurrent and in multiple schedules. N and n represent the number of responses and reinforcements, respectively; the subscripts represent the components of the multiple schedule or the concurrent operants; and a is a constant assuming the value 1.0 for concurrent schedules and ⅓ for multiple schedules. This equation was based on data obtained by Lander and Irwin and on data reported by Reynolds (1963).

Lander and Irwin (1968) suggested that $a = 1/3$ in multiple variable-interval, variable-interval (VI VI) schedules, and that $a = 1.0$ in concurrent VI VI schedules. However, results from a number of experiments suggest that in concurrent VI VI schedules the value of a may depend on the immediate consequences of changeovers between the concurrent schedules (Shull and Pliskoff, 1967; Todorov, 1969, 1971). For a given pair of unequal VI schedules, the relative rate associated with the most favorable schedule seems to increase (and so increases the value of a) as the rate of changeovers decreases. When the rate of changeovers is high, the subjects alternate responses on both schedules, and the relative response rate is insensitive to reinforcement distribution between the schedules ($a = 0$). If the relationships between relative response rate and relative reinforcement rate in concurrent VI VI schedules can be affected by the length of exposure to each schedule between changeovers (interchangeover time), it is possible that that relationship in multiple VI VI schedules also will be a function of the frequency of alternation of the schedules.

METHOD

Subjects

Three adult, White Carneaux pigeons were maintained at 80% of normal body weight determined during free access to grain. The subjects had previous experience with several reinforcement schedules.

Apparatus

A standard experimental box for pigeons, with two response keys (Ferster and Skinner,

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1957), was used. The left response key remained inoperative during the entire experiment; the right key was transilluminated either by a red or a green light. A minimum force of 0.09807 N was required to operate the response key. The reinforcer was a brief period (3 sec to one subject, 4 sec to another, and 6 sec to the third one) of free access to grain, presented to the pigeons through a solenoid-operated hopper.

Procedure

The key-pecking behavior of the pigeons had been established in previous experiments. Beginning with the first session in the present experiment, the subjects' responses were reinforced on a two-component multiple variable-interval variable-interval (*mult* VI VI) schedule of reinforcement.

VI schedule. A separate VI schedule was associated with each component. Interreinforcement intervals were based on an arithmetic scale. The schedules used were VI 30-sec and VI 90-sec. A reinforcement would be assigned to a component only when its associated keylight was on; otherwise, that tape puller would stop until its associated keylight came on again. When the tape puller stopped because a reinforcement was scheduled before the end of a given interval, it remained still until the next response associated with that schedule was reinforced.

Stimuli. The key was red when the VI 30-sec was in effect and green when VI 90-sec was in effect. Additional illumination in the chamber was provided by two houselights. During reinforcements, houselights and the keylight were turned off. Each response produced auditory feedback by operating a relay attached to the other side of the intelligence panel.

Component alternation. Component duration was arranged on a variable-interval basis according to an arithmetic progression. Minimum component duration in all average durations used was 3 sec. The maximum component duration would vary according to the average duration used at a given experimental condition. For any average duration it would be equal to the double of the average duration minus three. The other eight durations, scheduled according to an arithmetic progression, were $d_1 = 3$ sec, $d_6 = t$ sec, and $d_{11} = (2t - 3)$ sec. However, there was an exception. When average component duration was 5 sec, only five durations were used (3, 4, 5, 6, and 7 sec) due to technical problems. The red and green components alternated and had, at the end of a session, the same average duration. The average duration of the component schedules was, at first, 10 sec each. Table 1 shows the values of average component duration investigated and their order of presentation. As the tape arranging component duration stopped when the feeder was operated, the occurrence of a reinforcement in a component did not reduce the time during which the subject could respond in that component.

Other contingencies. Contrary to the procedure used by Shimp and Wheatley (1971), no changeover delay was scheduled to prevent reinforcement of the first response in each component. When a component ended during the emission of a burst of responses, reinforcement could be initiated in a component different from the one in effect when the response burst started. The sequence of variable component durations was intended to diminish the probability of the development of different response rates in different parts of each period of exposure of the schedules. When fixed component durations are used, there is the possibility of a high response rate in the last seconds of the least-favorable component maintained by the probability that a reinforcement will be assigned as soon as the other component is in effect.

There was no cancelling of reinforcements arranged but not produced before a stimulus change. That reinforcement would occur after the first response emitted on the return of the component in which the reinforcement was arranged.

A session was terminated when the sixtieth reinforcement occurred. Because of this procedure, the sums of seconds of exposure for each component could be slightly different in any given session. The totals of time of exposure of each component (fourth and fifth columns in Table 1) and the totals of reinforcements (sixth and seventh columns) show that the procedure did not change the scheduled frequency of reinforcements per unit of time in each schedule.

Training under all component durations was continued for at least 14 daily sessions and until the rate of responding in both components was judged to be stable over the last five sessions. The stability criterion was the

Table 1

Original data totalled across the last five sessions in *Mult* VI 30-sec (red) VI 90-sec (green).

Average Comp. Duration (Sec)	*Sessions*	*Responses* Red	*Responses* Green	*Time (Sec)* Red	*Time (Sec)* Green	*Reinf* Red	*Reinf* Green
		P-14					
10	15	6967	2925	6689	6609	225	75
40	16	5896	3428	6877	6837	223	77
10	19	6424	2999	6785	6808	222	78
5	17	6017	2635	6924	6912	225	75
150	16	5941	2971	7044	6288	228	72
300	17	5181	3346	6816	6758	223	77
5	16	6571	3067	6825	6787	222	78
		P-16					
10	14	4151	1353	6676	6640	231	69
40	21	3173	1572	7146	6705	228	72
10	18	2810	1654	7232	7059	225	75
5	14	4193	1960	7006	6794	227	73
150	16	3916	2789	6972	7193	223	77
300	17	3298	2716	6811	7609	216	84
5	16	3862	1695	7030	6976	228	72
		P-17					
10	15	8087	2701	6648	6621	227	73
40	16	9123	4122	6780	6819	223	77
10	19	10158	4323	6764	6846	224	76
5	17	9752	4549	6823	6840	225	75
150	16	8482	4891	6910	6576	226	74
300	17	7755	4916	6925	6592	227	73

absence of upward or downward trends on relative response rates in a component, plotted against sessions, over the last five sessions.

RESULTS

The original data from each subject, totalled across the last five sessions, are presented in Table 1. From these data the rate of responding under each VI schedule was computed. Response rate is here defined as the number of responses emitted in the presence of a given schedule divided by the time spent in the presence of that schedule (reinforcement time excluded). Relative response rate is here defined as the rate under a given schedule divided by the sum of rates under both schedules.

Figure 1 shows how the relative response rates under VI 30-sec changed with manipulations in average component duration. The solid line connects the mean of the group of points from each component duration. Relative response rates on the most favorable schedule seems to be a generally decreasing function of average component duration.

Figure 1 also shows part of the data reported by Shimp and Wheatley (1971). The dashed line connects the means of three pigeons. The dotted horizontal lines represent the points at which relative response rates would match relative reinforcement rates on the two sets of data (0.80 in the experiment by Shimp and Wheatley and 0.75 in the present experiment). Relative response rate in the Shimp and Wheatley experiment also seems to be a decreasing function of component duration.

As the component duration decreased, in both experiments, the relative rate of responding in a component deviated away from the value predicted by equation 1 (0.61 for the Shimp and Wheatley experiment and 0.59 for the present experiment), given Lander and Irwin's (1968) suggestion that $a = 1/3$ in multiple schedules. The deviations increase toward the values of relative rate of reinforcement of each schedule as component duration is reduced to 10 sec or less in both experiments. When the average component duration was 5 sec in the present experiment, the relative response rate was not quite as close to the relative reinforcement rate as when the average

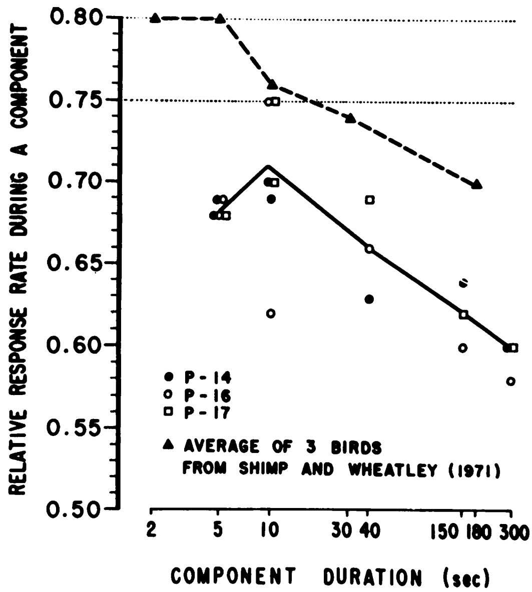

Fig. 1. Relative rate of responding as a function of average component duration in *mult* VI VI. The solid curve was drawn connecting the mean point at each component duration, and represents the data from all three subjects. The dashed curve represent data from a similar experiment conducted by Shimp and Wheatley (1971). The dotted lines indicate the relative rate of reinforcement on each experiment. It was 0.75 for the present experiment and 0.80 for the Shimp and Wheatley experiment.

duration was 10 sec, but it was still closer to matching the relative reinforcement rate than to the value predicted by equation (1). A similar finding is reported by Shimp and Wheatley with respect to the lowest component durations (2 sec and 5 sec) used during their experiment.

DISCUSSION

The results clearly show the importance of component duration in the determination of response rates in *mult* VI VI schedules. In all cases, response rates were higher in VI 30-sec than in VI 90-sec, but the discrepancy in the rate produced by the two schedules tended to be the greatest when the duration of the component was short.

When the average component duration was 150 sec or 300 sec, close to the 180-sec fixed component duration used by Lander and Irwin (1968) and by Reynolds (1963), the function relating relative response rate to relative reinforcement rate was more like the relationships reported by those authors for *mult* VI VI schedules. When the average component duration was closer to interchangeover times commonly found in concurrent VI VI schedules, relative rates of responding tended to match relative rates of reinforcement.

Similar conclusions were presented by Shimp and Wheatley (1971) from an experiment that, in spite of several procedural details different from the present experiment, provided similar data. The differences in the general shape of the functions in Figure 1 may be related to: different relative rates of reinforcement used (0.80 and 0.75); different overall frequency of reinforcements per hour (±40 and 80), the use of a changeover delay of 1 sec by Shimp and Wheatley to prevent reinforcement in one component from occurring after a response burst initiated on the other component; the use of fixed component duration by Shimp and Wheatley, and of variable component duration in the present experiment; the way in which reinforcements were arranged—constant reinforcement per opportunity VI schedules used by Shimp and Wheatley and arithmetic VI schedules on the present experiment. These procedural differences notwithstanding, it can be concluded from both experiments that reductions in component duration in *mult* VI VI move the relative response rate toward a value equal to the relative reinforcement rate.

On the other hand, the data from short component durations indicate the possibility of a maximum for the function between component duration and relative response rate. Shimp and Wheatley reported that when the component duration was 2 sec, the relative response rate in a component sometimes was further from the relative reinforcement rate in that component than when component duration was 5 sec. In the present experiment, a similar relationship was found between durations of 5 sec and 10 sec. If one assumes that as component duration tends toward zero, the differential responding in the presence of the discriminative stimuli tends to disappear, it can be expected that relative response rate will tend to 0.50 as component duration tends to zero. However, it should be noted that for average component duration of 5 sec, the number of durations used (five) was lower than the number used on all other average durations (11). This difference determines an overrun at short durations, and might explain the difference in inclination on the left side of the functions shown in Figure 1.

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