

Effort and response rate¹

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Key pecking of pigeons was reinforced on a variable interval 2 min schedule. On alternate days the response force requirement was varied between 35 g and 175 g. Large differences in rate of responses above the force criterion were observed on the alternate days; however, no differences in rate of responding were found if all responses above a low force (15 g) were considered.

Two different measures of response rate have been used in the study of effortfulness of response. Chung (1965), for example, considers only the rate of responses which meet the reinforcement criterion. Another possibility is to consider the rate of a large class of responses, such as all responses which exceed some minimum effort value (Notterman & Mintz, 1965). Thus, even though the reinforcement criterion may be varied, the defining characteristics of the measured response remain constant. Investigations using this procedure with rats as experimental Ss (Notterman & Mintz, 1965; Skinner, 1938; Stanley & Aamodt, 1954) have found that in some situations the rate of response is invariant as the effort required to meet a reinforcement criterion is changed.

The present study resulted from an attempt to study interactions between effort and amount of reinforcement, varying effort by changing the force required to operate a pigeon key. In the course of the study, the response key was modified in such a way that a constant, low-force response could be measured in addition to the responses which met the reinforcement criterion. This additional response measure made it possible to determine whether the invariance of low force responding reported for rats could also be obtained with pigeons.

Subjects

Three white Carneaux pigeons were maintained at 80% of their free-feeding weights throughout the experiment. All Ss had been used in a number of prior experiments.

Apparatus

The experimental chamber was a Lehigh Valley Electronics pigeon box. The response key was a Lehigh Valley Electronics pigeon key which functioned in two ways: (1) Pecks on the key of 15 g force or greater opened a normally closed circuit formed by contacts mounted on the key and a copper plate upon which the contacts rested when the key was in an unoperated position, and (2) after the key had moved about 1/32 in., it encountered a hinged plate which if moved 1/16 in. activated a microswitch. The force required to move the hinged plate could be varied by compressing a spring against the plate. The peak force required to operate the microswitch was adjusted every day, and was accurate to within 2 g.

Reinforcement contingencies were programmed by standard relays and timers, and data were recorded on electrical impulse counters and a cumulative recorder. Reinforcement consisted of the presentation of a hopper containing mixed grain.

Procedure

During each daily session of 48 min duration, key pecking was reinforced on a variable interval schedule with an average interval of 2 min. Every 3 min the color of the key was alternated between blue and yellow. For S No. 5 each reinforcement in yellow was 2.25 sec in duration and in blue, 4.50 sec. For S No. 9 these durations were reversed with respect to color. For S No. 34 reinforcements were 4.50 sec in both key colors.

Two measures of responding were taken each day: (1) threshold responses, pecks on the key of 15 g force or greater, and (2) criterion responses, pecks on the key of sufficient force to actuate the microswitch. The force necessary to actuate the microswitch was alternated between 35 g and 175 g on successive days. The criterion responses were the only ones which actuated the reinforcement mechanism and a feedback relay in the chamber.

The birds had been reinforced on similar schedules for several months, with the present experiment beginning when the response key was modified for the recording of threshold responses. The animals were run on this procedure for 26 days and data presented are from the last 10 days.

Results

The major results are presented in Table 1. The last two columns of the table show the mean rates of criterion responses for the high and low force requirements for each S. Each mean is based on five days. The rate of criterion responses is dramatically different for the 35 g requirement as contrasted with the 175 g requirement. For each of the Ss the rate of responding is greater with the 35 g requirement. The differences range from a factor of 2 for S No. 9 to a factor of 14 for S No. 5.

In contrast to these differences in criterion response

Table 1.
Threshold and Criterion Responses per Minute
on 175 and 35 g Criterion Days

Subject	Threshold response rate		Criterion response rate	
	Criterion Force		Criterion Force	
	175	35	175	35
5	59.7	63.8	3.1	41.3
9	46.2	41.4	14.1	30.9
34	108.1	102.0	19.9	85.8

rates, mean threshold response rates from the same sessions do not vary significantly as a function of the criterion response force requirement.

The finding of marked differences in criterion response rates with no related differences in threshold response rates was essentially unaltered by the reinforcement duration factor. Criterion and threshold response rates determined for the separate reinforcement duration components indicated the same relationship to hold within each component.

Discussion

The results of the present study clearly indicate that threshold response rate is invariant under the changing criterion conditions imposed in this study. This extends the findings of previous studies which have used rats as Ss. Notterman & Mintz (1965) reinforced different groups of rats on a continuous reinforcement schedule for responses meeting different force criteria and found no differences in threshold rate between the groups. Skinner (1938) reinforced a single rat for responses of different forces on a fixed-interval schedule and found no difference in threshold rates under the different reinforcement criteria. Stanley & Aamodt (1954) found threshold response rates during extinction did not differ as a function of criterion force requirements during training or extinction. The invariance of threshold response rates in the present study indicates that the previous findings are not limited to the lever pressing behavior of rats.

There are several factors which may have contributed to the invariance of threshold responding found in this study. First, there may have been an induction effect from one day to the next. That is, the stimulus conditions associated with the different effort requirements may not have been sufficient to control different distributions of response force. However, as a general interpretation for the phenomenon, this explanation is weak, as Notterman and Mintz found threshold response invariance with independent groups.

Secondly, it is known that the response rate in the remote link of a two-link chain is dependent on the rate of reinforcement rather than the response rate in the terminal member (Autor, 1960; Herrnstein, 1964). If the key peck is considered a chain in which the

threshold response is an early member, then one would predict that rate of threshold responding would remain constant as long as frequency of reinforcement for criterion responses did not decrease.

A third possibly relevant factor is concurrent superstition (Catania & Cutts, 1963). With a micromolar approach to response definition (Logan, 1960), responses of different forces are different operants. The act of key pecking can then be considered a concurrent schedule, and the maintenance of responses below criterion force would be the result of these responses being followed closely in time by criterion force responses which are reinforced. Thus, the low-force responses may be maintained in a manner similar to the superstitious maintenance of spatially defined operants in the familiar multiple-manipulandum concurrent schedule setting.

Finally, the distinction between threshold responses and criterion responses is quite a critical distinction which must be made if one is to meaningfully discuss the effects of effort on response rate. A good deal of confusion may result if one attempts to infer the effects on threshold responses from criterion response data, as the present study illustrates that the two measures may not covary.

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Notes

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