BEHAVIOR STABILITY AND RESPONSE RATE AS FUNCTIONS OF REINFORCEMENT PROBABILITY ON "RANDOM RATIO" SCHEDULES^{1,2}

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A random ratio schedule is one under which every ordinaly specified response has the same probability of reinforcement as any other. Data have been gathered at several values of this type of schedule, using a separate group of pigeons for each schedule value and giving prolonged exposure to each value. No simple relationship was found between response rate and reinforcement probability. In general aspect group data from the present experiment agree with those from a single organism study cited. It was shown that 40 to 50 days of exposure to random ratio schedules yields fairly asymptotic response rate data. The tabulated raw data, and the results of some statistical manipulations, have been deposited with the American Documentation Institute.

In recent attempts to construct an integrated system for formulating reinforcement schedules, there has been elaborated a temporally defined framework within which the parameters of such schedules can be specified and experimentally approached (Schoenfeld, Cumming, and Hearst, 1956; Schoenfeld and Cumming, 1960). In general, the t system depends upon specifying reinforcement probability with respect to a time base, employing a repeating time segment or "cycle" divided into two periods of unequal reinforcement probability. Cycle length is designated as t , the period of higher reinforcement probability as t^D (typically with probability of unity prevailing), the period of lower probability as t^A (typically, though not necessarily, with zero probability of reinforcement prevailing), and the ratio $t^D/(t^D + t^A)$ as $\bar{T}$. Reinforcement probability may be varied by adjusting the relative proportion of time during which reinforcement is available with a probability of unity (Brandauer, 1958). When the total duration of a t cycle (or, $t^D + t^A$) is short relative to the minimal interresponse time of the organism, the probability of reinforcement for any response is determined by the ratio $\bar{T}$. The relative frequency (P) of reinforcement (S^R)

for any response, say the K th counted from the last occurrence of reinforcement, is completely predicted by the geometric probability distribution, $P(S^R) = pq^K$, where p is equal to $\bar{T}$ in the long run, and q is unity minus p . Such schedules, in which the probability of reinforcement is the same for all responses, have been termed "random ratio" schedules to distinguish them from "variable ratio" schedules in which, although it is possible to specify the mean and distribution of the number of responses required until a reinforcement occurs, the probability of reinforcement is not necessarily the same for every response.

The present study utilizes the random ratio schedule as defined above, allowing $\bar{T}$ to vary. The principal purpose is to record for reference by other workers some fairly extensive data regarding two matters: (1) the problem of behavior stability, and of criteria of stability, which has only rarely been dealt with (Cumming and Schoenfeld, 1960) despite its central importance in the design of steady state experiments; and, (2) the problem of comparability of group functions as against individual organism functions. Several groups of birds were exposed, each to a different random ratio schedule but covering the range of values which Brandauer (1958) used. The exposure at each $\bar{T}$ value was prolonged to permit examining the stability question again in the light of fresh data, the latter secured this time at several values of probability rather than with a single reinforcement schedule alone.

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Apparatus and Procedure

The subjects were 24 White Carneaux hen pigeons. The measured response was key-pecking, and reinforcement was a 3-sec presentation of a grain hopper. The experimental chambers were generally of the specifications given elsewhere (Ferster and Skinner, 1957). Cycle length was held constant at 20 msec and $\bar{T}$ was assigned values of 1.00 (regular reinforcement), 0.10, 0.050, 0.025, 0.0125, and 0.0068. After arrival in the laboratory, each bird was allowed *ad libitum* feeding for six weeks, during which samples were taken of its weight. Each bird was then reduced in weight until it had reached 80% of its free-feeding level, and at that time the key-pecking response was shaped. Each bird was then given 50 regular reinforcements on each of five consecutive days before the experiment proper began. The 24 birds were divided into eight groups of three each on a random selection basis. Each group was assigned directly after its regular reinforcement sessions to one of the values of $\bar{T}$, with the exception of groups 4s and 5s. They were included to provide data at the two smallest $\bar{T}$ values in the event that groups 4 and 5, which were directly assigned to those values, extinguished. Groups 4s and 5s thus also provide a comparison of effects of those low $\bar{T}$ schedules with and without prior behavioral shaping on intermediate schedules. Group 4s was placed on $\bar{T} = 0.025$ for five days before being moved to 0.0125 where it stayed for the remainder of the experiment; group 5s was placed on 0.025 for five days, then on 0.0125 for 15 days, before being moved to its terminal value of 0.0068.

Experimental sessions were daily, seven days per week, as long as a bird's weight was within ± 5 g of its 80% level. Preliminary studies indicated that the strict criterion range of ± 5 g could be maintained if the length of experimental sessions was properly chosen and post-session supplementary rations carefully estimated. It proved necessary for this purpose to expose group 0 ($\bar{T} = 1.00$) to its schedule for only 5 min per daily session, group 1 ($\bar{T} = 0.10$) and group 2 ($\bar{T} = 0.050$) for 10 min per session, and group 3 ($\bar{T} = 0.025$), group 4 ($\bar{T} = 0.0125$), group 5 ($\bar{T} = 0.0068$), group 4s ($\bar{T} = 0.0125$), and group 5s ($\bar{T} = 0.0068$) for 20 min per session. Computations of response rate in each session were "corrected" by subtracting

from session time 3 sec for each reinforcement obtained during the session, and dividing total responses by the remaining time.

Results and Discussion

Because of space limitations in the Journal, the data have been placed on deposit with the American Documentation Institute in two tables.³

Table I gives for each bird separately, for every day of exposure to its schedule, corrected rate in responses per second, total reinforcements procured (S^R), and responses per reinforcement (R/S^R). No bird ran fewer than 45 days, and some exposures extended up to 80 days. Figure 1 presents an estimate of stable group performance obtained by averaging the rate data for the three birds in each group after 45 days of exposure to the group's $\bar{T}$ value. The rate differences produced by the shaping procedure are quite large, especially for groups 5 and 5s at $\bar{T} = 0.0068$, but for both groups some low value of $\bar{T}$ must be reachable at which responding would extinguish.

Brandauer, (1958) using a single organism at various $\bar{T}$ values (and including, therefore, some measure of shaping for each bird), obtained rate data indicating a possible maximum at a $\bar{T}$ of about 0.02. While comparison of the present data with Brandauer's must be cautiously made, it may be pointed out that no systematic differences appear between our findings and his, with the exception of a shift in a peak toward lower $\bar{T}$ values in our study. Moreover, while no monotonic relationship exists, both studies find response rate to be higher at some small $\bar{T}$ values than at large ones, and both find response rate lower under regular reinforcement than at any value of $\bar{T}$ less than unity.

Table II contains the mean response rate in cumulative five-day blocks for each bird in each group, together with the 95% and 99% confidence intervals for each mean. These data may be used to evaluate some possible criteria of stability which are taken in steady state ex-

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Fig. 1. Corrected response rate at various reinforcement probabilities ($\bar{T}$). Each point is the mean value; based on the first 45 days of exposure, for the three birds in each group working at a particular $\bar{T}$ value. Points in brackets are for the two "shaped" groups designated with an "s" in the text and in the data tables deposited with ADI.

periments to be estimates of final representative performance. Figure 2 presents data on the stability of response rate for one bird taken at random from each group. Visual inspection of Fig. 2 (and Table II) shows for the un-shaped birds that an interval estimate of the mean response rate taken on the basis of 40 to 50 days of exposure to all but the smallest of two $\bar{T}$ values would encompass the mean response rate obtained when the birds are exposed for any greater number of days. For the shaped birds at the two lowest $\bar{T}$ values (43s and 52s) the 40 to 50 day figure obtains also. This result agrees well with the stability data reported by Cumming and Schoenfeld (1960) for a t -schedule of 30 sec cycle length and $\bar{T} = 0.05$.

Fig. 2. Mean and .05 confidence limits for corrected rate of responding in cumulative five-day blocks over the entire course of the experiment. Data are shown for one bird selected at random from each group.

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