EFFECTS OF VARYING CYCLE LENGTH IN A τ REINFORCEMENT SCHEDULE¹

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A temporally defined reinforcement schedule within the τ system of classification was studied, with pigeons as subjects and with cycle length as the independent variable. As cycle length decreased, response rates increased, responses-per-reinforcement went through a maximum, while the number of reinforcements-per-session increased. The first two functions are attributed to changes in the discriminability of the τ^D and τ^A components of the cycle, while the latter seems to result from changes in the relative durations of reinforcement time and τ^A time.

Schoenfeld and Cumming (1960) have proposed the " τ system" as an extension of their earlier t classificatory schema for reinforcement schedules (Schoenfeld, Cumming, and Hearst, 1956). A τ schedule is one in which periods of non-reinforcement, or lesser probability of reinforcement, τ^A , are interspersed with periods, τ^D , in which each response has a greater probability of reinforcement, the latter probability being equal for all responses in τ^D . Each τ^D is composed of t^D and t^A segments which alternate rapidly, each coincidence of a response with t^D being reinforced. The probability of reinforcement for any response within τ^D is therefore $t^D/(t^D + t^A)$, or $\bar{T}$. The proportion of time within any τ cycle in which τ^D is present is designated as $\bar{\tau}$. Snapper (1962) has shown that behavior under this schedule is sensitive to changes in $\bar{T}$ and to variation in $\bar{\tau}$. The present paper reports several behavioral functions resulting from variation in the length of the τ cycle.

METHOD

Subjects

Six White Carneaux adult hen pigeons (Ss) were used. The data from only five of these are presented, however, since one required repeated reshaping of the key-pecking response during the study, making its experimental history somewhat different from that of the other birds. On arrival in the laboratory, Ss

were put on *ad libitum* food and water for about one month over the latter part of which each S's daily weights were averaged to give its standard 100% body weight. Thereafter, through food deprivation, the weight of each bird was reduced to 80% of *ad lib* value and maintained at this level throughout the experiment.

Apparatus

The experimental enclosures and programming equipment were the same as those used by Snapper (1962). In general, the experimental enclosure consisted of a soundproofed aluminum box divided into an illuminated animal chamber containing a single response key, and an apparatus section containing the food hopper (reinforcer) and various electrical connections. Air was forced through the box during experimental sessions to provide ventilation for the birds and a measure of sound masking.

Procedure

Animals were run seven days a week providing that their body weights at the beginning of a session were within $80\% \pm 15$ g of free-feeding weights. Water was available at all times in the living cages but not in the experimental chamber. Reinforcements consisted of 3 sec access (via food hopper presentation) to a grain mixture of 50% Kaffir, 40% vetch and 10% hemp seed. Animals were weighed at the close of each session and fed a quantity of maple peas sufficient to bring their weights to the prescribed range by the start of the next day's session. All experimental

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sessions were 1 hr long and began with a τ^D period.

Initial training consisted of "shaping" the key-pecking response, followed by five consecutive days on which 50 regular reinforcements daily were provided for the response. Immediately after this training, Ss were placed on the experimental schedules. *Tau* cycle lengths of 600, 450, 240, 120, 60, 30, 15, and 7.5 sec duration were used, in that order. In all cases, $\bar{\tau}$ was 0.20, $\bar{T}$ in τ^D was 0.02, and $\bar{T}$ in τ^A was 0.00. The Ss were given 60 days of exposure to the first schedule and 30 days to each subsequent schedule.

RESULTS AND DISCUSSION

Table I shows for each of the five Ss, and for each of the schedules, response rates in responses-per-sec corrected for the total reinforcement presentation time, the number of responses-per-reinforcement, and the number of reinforcements for each session. The data given are means for the last 10 days of exposure to each schedule, these being taken as

stable representative values of the final "steady state" reached on each schedule. Figure 1 plots the group means for all five Ss for these variables, since the means do not seem to violate the individual trends.

As the *tau* cycle is shortened, mean rate of responding at first remains low but then increases and levels off at a somewhat higher value. This function may perhaps derive from the following considerations. At long cycle lengths, all Ss display a temporal discrimination, responding rapidly throughout τ^D , and halting completely ("breaking") in the early portion of τ^A , a pattern reminiscent of behavior under fixed interval schedules. While τ^D rate is high, the overall response rate remains low because a large fraction of the whole cycle (i.e., in τ^A) is consumed by the "break". When the *tau* cycle is reduced in length, however, the discrimination between τ^D and τ^A becomes more difficult to make. In any *tau* schedule such as the present, where no exteroceptive cue parallels the presentation of τ^D , the onset and offset of τ^D is of low discriminability at best. As *tau* cycle length is shortened, with

Table I

Experimental measures at each *tau* cycle length. The latter are expressed in seconds, with τ^D and $\tau^D + \tau^A$ (the latter in parentheses) given separately. Table entries for the individual birds are means for the last 10 days of exposure to each cycle length. Corrected rate in responses-per-sec, responses-per-reinforcement (Rs/S^R), and reinforcements-per-session (S^Rs/session) are entered. The bottom part of the table contains the means of the individual entries. For other details, see text.

		τ^D and ($\tau^D + \tau^A$) in seconds							
		120 (600)	90 (450)	48 (240)	24 (120)	12 (60)	6 (30)	3 (15)	1.5 (7.5)
Bird 302	Corrected rate	0.92	0.67	0.98	1.23	1.15	1.32	1.65	1.75
	Rs/S ^R	174.2	193.8	160.2	249.8	226.4	203.4	213.9	209.5
	S ^R s/session	19.4	13.6	22.5	22.2	19.8	23.9	27.5	30.5
Bird 303	Corrected rate	0.90	1.02	1.28	1.91	1.97	2.17	2.26	2.48
	Rs/S ^R	123.9	139.8	146.6	193.5	236.3	215.7	196.3	198.9
	S ^R s/session	27.5	27.4	31.9	35.7	29.9	37.2	41.2	44.4
Bird 304	Corrected rate	1.54	1.97	2.49	2.75	2.13	2.46	2.15	2.67
	Rs/S ^R	181.9	181.5	200.9	276.9	244.3	203.9	205.4	219.8
	S ^R s/session	29.9	31.7	43.9	36.0	31.0	42.6	37.2	43.5
Bird 305	Corrected rate	1.51	1.27	1.40	1.86	1.75	2.29	1.93	1.60
	Rs/S ^R	181.4	137.6	159.8	180.6	213.0	203.4	221.4	160.9
	S ^R s/session	32.6	34.3	31.7	36.2	29.9	39.9	31.8	36.3
Bird 306	Corrected rate	1.23	0.82	1.16	1.53	1.72	1.49	1.50	1.37
	Rs/S ^R	258.6	212.0	182.0	243.6	233.5	206.8	185.1	125.6
	S ^R s/session	17.5	15.9	23.8	23.3	26.5	26.3	30.8	41.7
Means	Corrected rate	1.22	1.15	1.46	1.86	1.74	1.95	1.90	1.97
	Rs/S ^R	184.0	172.9	169.9	227.1	230.7	206.6	204.4	182.9
	S ^R s/session	25.4	24.6	30.8	30.7	27.4	34.0	33.7	39.3

attendant reduction in the length of τ^D , this discriminability diminishes still further and the behavioral transitions from τ^D to τ^A consume a larger fraction of the *tau* cycle. This effect is evidenced in behavior by a decrease in the amount and proportion of time spent

in non-responding during τ^A (see Fig. 2). When τ^D becomes wholly indiscriminable from τ^A ,

Fig. 1. Group means of corrected response rate, responses-per-reinforcement, and reinforcements-per-session as functions of *tau* cycle length.

Fig. 2. Cumulative response curves illustrating the shift in pattern of responding between the longest cycle length in the study (600 sec, in the upper panel) and that at which this S gave its maximum number of responses-per-reinforcement (120 sec, in the lower panel). The pips on the records indicate reinforcements delivered. Bird No. 302 was selected by lot for this illustration, and the curves shown are from its last 10 criterion days on each schedule. The two record segments were cut from parallel early locations in the two daily sessions from which they were extracted. Beneath each segment, τ^D is indicated by black bars, τ^A by open double lines.

the S responds throughout the cycle at the τ^D rate.

At the latter uniform rate, the S's behavior seems "inefficient". With τ^D indiscriminable from τ^A , an average of 250 responses for each reinforcement would be expected, since the animal spends $\frac{1}{5}$ of its time in τ^D and $\frac{1}{50}$ of its responses in τ^D are reinforced. As can be seen in the second panel of Fig. 1, the ratio of responses to reinforcements actually approaches 250:1 in the cycle range where discrimination is breaking down. As τ cycle length decreases further, however, the rate of responding remains high, while the "efficiency" of responding, in responses-per-reinforcement, begins to increase again. This latter rise may result from the fact that, at short τ cycle lengths, the duration of reinforcement begins to encroach more upon τ^A time than upon τ^D time. In effect, a reinforcement acts to change

the value of $\bar{\tau}$ by decreasing τ^A . More and more of the S's responses fall within τ^D , so that the overall probability of reinforcement is increased. The bottom panel in Fig. 1 shows this increase in the number of reinforcements-per-session as cycle length decreases.

REFERENCES

- Schoenfeld, W. N., Cumming, W. W., and Hearst, E. On the classification of reinforcement schedules. *Proc. Nat. Acad. Sci.*, 1956, **42**, 563-570.
- Schoenfeld, W. N. and Cumming, W. W. Studies in a temporal classification of reinforcement schedules: Summary and projection. *Proc. Nat. Acad. Sci.*, 1960, **46**, 753-758.
- Snapper, A. G. Properties of behavior under response-independent temporally defined reinforcement schedules. Unpublished doctoral dissertation, Columbia University, 1962.

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