STIMULUS CONTROL AND THE RESPONSE-REINFORCEMENT CONTINGENCY¹

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Pigeons were trained under a schedule in which reinforcement was made available at varying periods of time after a prior reinforcement. The first key peck after a reinforcer was available began a timer and a second key peck, which exceeded a specified minimal time interval, produced the reinforcer. It was shown that a contingency which contains a minimal inter-response time does not necessarily weaken stimulus control by an exteroceptive stimulus.

Hearst, Koresko, and Poppen (1964) found that generalization gradients after training with differential-reinforcement-of-low-rate (DRL) schedules were flatter than gradients after a variable-interval (VI) 1-min schedule of reinforcement. Differential-reinforcement-of-low-rate schedules provide positive reinforcers only if a response follows the preceding response by a minimal time interval, this interval being the parameter of the DRL schedule. Thus, a DRL 10-sec schedule would make the presentation of a food reinforcer contingent upon a response which followed a prior response by at least 10 sec. Hearst *et al.* (1964) assumed that "... DRL behavior is relatively more dependent than VI on internal, nonexteroceptive stimuli, since these kinds of stimuli are presumably involved in mediating the temporal discriminations and collateral behavior characteristic of DRL . . ." (p. 370). They then suggested that since the primary cues are proprioceptive in nature, exteroceptive stimuli might gain little control over key pecking.

The present paper examines this suggestion by reference to some data from a prior publication (Yarczower, Dickson, and Gollub, 1966) and some additional data not previously published. Data were collected from pigeons exposed to tandem (*tand*) variable-interval (VI) differential-reinforcement-of-low-rate (DRL) schedules of reinforcement. A tandem schedule makes access to reinforcement contingent

upon two schedules in succession without correlated exteroceptive stimuli (Ferster and Skinner, 1957). In the *tand* VI DRL schedule, reinforcement is made available at varying periods after the previous reinforcement, according to the VI schedule. When a reinforcement is available, only a response with a specified minimal interresponse time (IRT) can be reinforced. Tandem VI DRL schedules contain the same response-reinforcement contingency (namely, a minimal IRT required for reinforcement) as do DRL schedules. Will *tand* VI DRL schedules, like DRL schedules, result in flatter gradients of generalization than VI schedules of reinforcement?

METHOD

Procedure

The procedures for all but one of the groups of pigeons are presented in detail elsewhere (Yarczower *et al.*, 1966).

Briefly, 16 naive pigeons were divided into four groups of 3, 4, 4, and 5 birds. All subjects were magazine trained and then trained to peck a key transilluminated by a 550-nm light. Two groups were exposed to multiple schedules with two stimuli of different wavelengths and two groups were exposed only to a stimulus of single wavelength.

One of the two groups exposed to the two different wavelengths received a multiple schedule which alternated a variable-interval 30-sec (VI 30-sec) schedule of reinforcement with a period of nonreinforcement. In this multiple schedule, when the key light was illuminated by a 550-nm light, key pecks were followed by access to the food magazine after

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varying periods of time averaging 30 sec, and when the key was illuminated with the 570-nm light, no key pecks were followed by access to the food magazine, *i.e.*, extinction (EXT). The generalization gradient for this group is to be compared with the gradient for the other group exposed to a multiple schedule; 570 nm was paired with extinction, but 550 nm was paired with a *tand* VI 30-sec DRL 4-sec schedule of reinforcement.

The remaining two groups received training only with the 550-nm light. These two groups differed with respect to the schedule of reinforcement in effect during the 550-nm light. For one group, a VI 30-sec schedule was in effect in the presence of 550 nm and for the other group a *tand* VI 30-sec DRL 4-sec schedule was in effect.

The groups given discriminative training received two 4-min trials of the stimulus correlated with reinforcement (S+) alternated with two 4-min trials of the stimuli not correlated with reinforcement (S-) until a total of 20 trials had been received. The two groups given only S+ training received ten 4-min trials. All trials were separated by a 10-sec timeout during which lights were turned off and reinforcements were not available. Training continued until response rates were relatively stable. The groups received the following amounts of training: VI 30-sec: 10, 10, 16, 20 sessions; *tand* VI 30-sec DRL 4-sec: 13, 14, 14, 15 sessions; *mult* VI 30-EXT: 16, 16, 16 sessions; *mult tand* VI 30-sec DRL 4-sec-EXT: 11, 12, 12, 13 sessions.

After training on the appropriate schedules, generalization tests were conducted. The tests consisted of presentations of seven test stimuli

in irregular order for 30 sec with a 10-sec key-light off period separating each test stimulus. There was a total of 56 test trials, eight presentations of the seven test stimuli (520 to 580 nm in 10-nm steps). No food reinforcers were available during tests.

RESULTS AND DISCUSSION

Table 1 presents rates of responding for all subjects and shows response rate on the last day before testing as well as the range of response rates over the 10 days before tests. The DRL component clearly produced lower rates of responding than its comparison group. Finer analyses of the training data have been presented elsewhere (Yarczower *et al.*, 1966). The data of specific interest are presented in Fig. 1. Does a schedule of reinforcement in which access to a food reinforcer is contingent upon a minimal IRT necessarily result in weak stimulus control of key pecking by an exteroceptive stimulus? A comparison between the generalization gradients of the pigeons exposed to the *tand* VI DRL schedule and the group exposed to the VI schedule yields no noticeable differences. Similarly, a comparison between the two groups of pigeons given discriminative training again shows highly similar gradients for the two groups.

Birds given discriminative training emitted a significantly (Mann-Whitney U tests) greater proportion of their responses to test stimuli of longer wavelengths than S+ than did birds given only S+ training. Discriminative training clearly produced a shift in the distribution of responses in the presence of wavelength stimuli. The difference between the two

Table 1

Responses per minute for birds on the day before generalization tests. Also presented is the range of response rates over 10 days of training before testing.

Schedule	Response Rate Day before test	Range of Response Rates	Schedule	Response Rate Day before test	Range of Response Rates
VI DRL	13.2	8.4 - 15.0	VI	74.4	74.4 - 84.9
	15.6	10.8 - 21.0		42.9	22.0 - 46.7
	15.6	15.6 - 25.2		51.0	47.0 - 67.8
	20.4	16.2 - 22.8		51.6	20.0 - 64.3
VI DRL-EXT	14.4	14.4 - 22.8	VI-EXT	66.0	39.6 - 67.8
	17.4	16.8 - 20.4		54.0	32.4 - 58.2
	18.6	16.8 - 26.4		48.0	33.6 - 58.8
	14.4	10.8 - 22.8

Fig. 1. Mean per cent total responses during generalization tests. The discriminative stimulus for all groups was 550 nm, and 570 nm was the wavelength in the presence of which extinction was scheduled for the two groups exposed to a multiple schedule.

groups given discriminative training cannot be said to be significantly different. The per cent of total responses emitted in the presence of the peak stimulus has been used as an index of gradient steepness (Hiss and Thomas, 1963). The following percentages are the per cent of total test responses for each bird: VI 30-sec: 25.4, 27.6, 38.6, 45.5; *tand* VI 30-sec DRL 4-sec: 24.2, 27.2, 33.3, 43.2; *mult* VI 30-sec EXT: 32.4, 42.2, 44.0; *mult tand* VI 30-sec DRL 4-sec EXT: 33.5, 36.8, 38.4, 38.7. The groups cannot be said to differ significantly from one another (Mann-Whitney U test).

Which of the many procedural differences between the present study and Hearst *et al.* (1964) are responsible for the differences in results? An important difference is the present use of a *tand* VI DRL schedule and the use of a DRL schedule by Hearst *et al.* (1964). In a *tand* VI DRL schedule not all responses which meet the criterion of occurring after a

minimal interval of time are reinforced. Only after the first component, the VI, is satisfied will a reinforcer follow a response emitted after a minimal time interval. In contrast, a DRL schedule provides that a food reinforcer follow each response emitted after a minimal time interval. Similarly, under a DRL schedule but not under a *tand* VI DRL schedule, reinforcement is postponed by each response emitted after an interval shorter than that required.

It is possible that control of key pecking by an exteroceptive stimulus is weakened because key pecks come under the control of other cues consistently associated with reinforcement. It is possible, though not inevitable, that control by these other cues may reduce stimulus control by the exteroceptive stimulus associated with the reinforcement schedule.

In any case, weak stimulus control of key pecking by an exteroceptive stimulus is not necessarily the result of schedules of reinforcement which contain a response-reinforcement contingency requiring a minimal interresponse time.

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