Properties of the fixed-interval S^D

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After fixed-interval training, pigeons were given three generalization tests with novel stimuli. In all cases, responding increased during test intervals, but the amount of elevation varied among tests. These and other data provide support for an analogy between FI and Pavlovian delayed conditioning, although Pavlov's simple interpretation of the latter remains open to question.

It is of theoretical interest to determine the properties of the discriminative stimulus (S^D) after fixed-interval training, particularly since the FI is similar in some respects to Pavlovian delayed conditioning (Pavlov, 1927). One method of determining these properties is by observing the effects on behavior of varying the S^D after FI training. This has been done in two general ways.

The first method (e.g., Konick & Thomas, 1968; Zeiler, 1969) has employed generalization tests carried out in extinction, with time-out periods marking the beginning and end of an interval. Several test stimuli, varying in similarity to the training stimulus, were presented many times, and responding took the form of decremental gradients around the training stimulus. These results indicate that the fixed-interval S^D gains excitatory properties which generalize to neighboring stimulus values, as is the case after other types of training (see Zeiler, 1969).

A second method of testing is the introduction of a novel stimulus throughout occasional intervals after FI performance has stabilized, with other aspects of training left unchanged (Flanagan & Webb, 1964; Hinrichs, 1968; Singh & Wickens, 1968). The outcome of this procedure has been reported as a short-lived disruption of the normal scallop. Responding increases during the first half of the interval and decreases during the second half, resulting in a steady level of responding through the interval. These authors interpreted their results as analogous to the "disinhibition of delay" reported by Pavlov (1927).

This method of testing is probably better suited to fixed-interval behavior than is the method of testing in extinction. The omission of

reinforcement, even when time-out periods are used, unnecessarily adds a second variable to the testing situation. Extinction testing may be more suitable after VI training, where reinforcement does not usually directly control the temporal pattern of responding, but its usefulness has been called into question even there (Blough, 1965).

The present experiment was a compromise between the two methods; in the first condition a number of test stimuli each appeared several times in a randomized sequence, while in two other conditions one test stimulus appeared infrequently. Reinforcement was maintained during presentations of test stimuli. In all conditions, introduction of test stimuli was correlated with increased response rate.

SUBJECTS

Four experienced White Carneaux pigeons were reduced to 80% of their free-feeding weights and were maintained at this weight throughout the experiment.

APPARATUS

The experimental chamber was a 33 x 33 x 33 cm box with a 1.9-cm translucent key mounted on one wall. Visible on the key was a line produced by a Tektronix Model 503 oscilloscope; a lens mounted between the scope face and the key focused the image on the key (the image was a line

orientation approximately 1.3 cm long and .5 mm wide, as it appeared on the key). A half-silvered mirror was mounted between the scope face and the key. A bright red spot (approximately 3 mm in diam) produced by a modified stimulus projector mounted at right angles to the box and oscilloscope could be added to the center of the display by reflecting the projector's image from the mirror to the key. The spot was surrounded by a bright red halo, filling the key. A movable hood enclosed the area from the scope face to the box. Reinforcement (3-sec access to mixed grain) was available from a magazine whose aperture was located 5.08 cm below the key. The 6-W houselight and the key display were turned off during reinforcement. White noise and a ventilation fan served to mask any extraneous noises. All programming and recording equipment was located in an adjacent room.

PROCEDURE

After magazine and key training, all birds were run for one session on a VI 1-min schedule. The following day, training was begun on FI 50 sec in the presence of the vertical (90-deg) line orientation. Responding stabilized by the fifth week of training and testing was begun.

Condition 1

Two birds (56 and 72) were presented 40 50-sec fixed intervals, each correlated with one of eight line orientations [180, 157, 135, 112, 90 (vertical), 67, 45, or 22 deg] randomized in five blocks of eight. Reinforcement occurred at the end of each interval, independently of key pecking.

Condition 2a

Two other birds (3-30 and 62) were presented 10 50-sec warmup intervals with the training stimulus (vertical line orientation) on the key, followed by five presentations in which the horizontal (180-deg) orientation replaced the vertical. Each of the test intervals was separated by five

Fig. 1. Responding during the last 10 sec of the interval in the test stimuli presented in Condition 1. Individual data for Birds 56 and 72.

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intervals paired with the training stimulus. Reinforcement occurred independently of responding, as in the first condition.

Condition 2b

Training was resumed for 9 days, and all four birds were tested as in Condition 2a, but with the addition of a red light projected onto the key during presentations of the horizontal orientation.

RESULTS

Condition 1

The results of the first test, comprised of five blocks of eight orientations each (including the training orientation) showed no consistent differences in the scallop as a function of orientation. However, examination of total responses in the various orientations during the last 10 sec of the interval yields the gradients shown in Fig. 1. The M-shaped function is quite clear in the data of both birds. Though it was clearest at the end of the interval, it was evident to a lesser extent earlier in the interval.

Condition 2a

Figure 2 shows responding (averaged over the two animals) during the five presentations of the horizontal orientation compared with those presentations of the training orientation (vertical) which preceded test stimulus presentations. Response level during the later part of the interval was substantially higher during the test stimulus presentations, and a low level of responding appears during the early part of the interval, not only during 180 deg, but during the training stimulus as well.

Condition 2b

This condition was identical to the preceding condition, but included the addition of a red light to the key display and was administered to all four animals. Results (Fig. 3), averaged across the four birds, show that responding during the test trials was far greater than that in the training stimulus throughout the length of the interval, but reached a final level about equal to that reached in the training stimulus. These results are representative of data for individual birds.

DISCUSSION

Variation of SD during FI training almost invariably increased response rate. This was true when test stimuli were frequently presented, as in Condition 1, or when they were only occasionally presented, as in Conditions 2a and 2b. Responding during the training stimulus was very stable across conditions; with the exception of a slight elevation during the first half of the interval in Condition 2a (Fig. 2), a clear scallop was present during every test.

Fig. 2. Responding during Test 2a averaged over Birds 3-30 and 62. Responding in the test stimulus (180 deg) compared with responding during those presentations of the training stimulus (90 deg) which preceded a test stimulus presentation.

Aside from the general finding of elevated responding during test stimulus presentations, there was some indication of a correlation between degree of elevation and particular test stimuli. The difference in behavior during Conditions 1 and 2a, where the test stimuli were line orientations, and Condition 2b, where a red light appeared with an orientation, suggests a difference in effectiveness of orientation vs color test stimuli after training with an orientation SD.

A second indication of the differential effectiveness of test stimuli is the finding of the M-shaped gradients shown in Fig. 1 during Condition 1. The form of the gradients makes interpretation difficult, but in almost every test orientation, responding is higher than in the training stimulus.

The finding of elevated responding with variation in SD is not in agreement with studies finding

Fig. 3. Averaged responding of the four animals in Condition 2b. Responding in the test stimulus (180 deg and red light) compared with responding during those presentations of the training stimulus which preceded a test stimulus presentation.

decremental gradients around SD (Zeiler, 1969) or a lowering of the scallop (Konick & Thomas, 1968) in testing after FI training. Since both of these studies conducted testing in extinction, the disparity in results may reflect the effects of this factor.

Differences between the present results and those of Flanagan & Webb (1964), Hinrichs (1968), and Singh & Wickens (1968) at first seem not so easily reconciled. Their findings of temporary disruption of the scallop, with elevated responding during the first half of the interval and decreased responding during the second half are similar to Pavlov's (1927) description of the ideal case of disinhibition during delayed conditioning (disinhibition of delay). This similarity suggests that fixed-interval responding is analogous to Pavlovian delayed conditioning.

Results found here, while unlike those of these authors, likewise support a fixed-interval/delayed-conditioning analogy. Though Pavlov stressed the significance of data illustrating the *ideal* case of disinhibition of delay, he was prepared to accept a variety of effects as consistent with the disinhibition hypothesis. Examination of his data (Pavlov, 1927, pp. 93-98), comparing responding during test trials with responding during the immediately preceding trial, shows that the ideal case of disinhibition did not always occur. Of nine illustrations, an effect clearly showing elevation of responding during the first half of the delay period and a depression during the second half occurred in only four cases. In three other cases, little or no increase occurred during the first half of the delay period, while in three cases responding was elevated during the second half of the period. Both of these effects occur in the same illustration in two cases. Thus data comparable to that appearing in the first two conditions of the present experiment (elevation in responding during the second half of the interval, with no effect during the first half) exist in Pavlov's illustrations. The results of Condition 2b, where responding was elevated throughout the interval, with no change in response rate immediately preceding reinforcement, do not appear in any of the illustrations; a description of this effect does, however, appear in his text (pp. 94-95). Pavlov explained this wide range of effects as the result of the differing "physiological" strengths of the disinhibiting stimuli relative to the strength of the inhibition of delay.

The demonstration of an analogy between fixed-interval training and delayed conditioning, while informative in its own right, can shed

light on the mechanism underlying fixed-interval behavior only to the extent that credence is given to Pavlov's simple interpretation of delayed conditioning as strong inhibition and weaker excitation during the early part of the delay period which gives way to increasing excitation as the end of the period approaches. Probably the strongest evidence for this interpretation is the demonstration of the "ideal" case of disinhibition; i.e., elevation in responding during the first half of the delay period and depression during the later part of the period (cf. Staddon, 1969). Pavlov's illustrations, however, show that this effect is only one of a variety of possible outcomes, since the "strength" of the disinhibiting stimulus, as well as the strength of inhibition of delay, may vary widely. This account is not wholly satisfying; convincing support would have to begin with some ranking of stimuli according to "inhibitory strength" by a method other than the observation of their effects during the delay period, as was done by Pavlov. The results of their presentation during the delay period (or during the fixed interval) could then be compared with

the various outcomes predicted by Pavlov.

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Partitioning of a restricted food source in a territorial iguanid (*Anolis carolinensis*)*

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Following a 48-h deprivation period, time samplings of behavior of six pairs of lizards were taken from 9:30 a.m. to 5:40 p.m. each day for 5 days. Each pair of Ss was observed in an area 32 x 32 x 16 in. In all pairs, one animal dominated and supplanted the other throughout the observation area. Food offered during the first day of observation was taken in equal amounts by the dominant and nondominant lizards; food offered on the fifth day was taken almost exclusively by the dominant animals (90.4%). This increase is statistically significant ($p < .031$) and suggests that a territory can function to ensure the holder of that territory all or most of a limited food supply.

A number of authors have suggested that territoriality may serve as a mechanism for assuring an adequate share of the food supply for some minimum number of individuals (e.g.,

Altum, 1868; Hediger, 1950; Howard, 1929; Rand, 1967). One prediction which can be derived from this hypothesis is that, under conditions of a food shortage, a territory holder will take all or most of the food available within its territory. This study is a test of this prediction in a territorial Iguanid, *Anolis carolinensis*.

METHOD

Eighteen adult male *Anolis carolinensis*, obtained commercially,

were maintained, nine each, in two glass terrariums, 18 x 10 x 9.5 in. The tanks were placed opposite a window with an eastern exposure. Normal daylight was augmented from 5 a.m. to 9 p.m. by a 40-W incandescent bulb, placed 4 in. above each tank top. The tanks were heated from below and maintained at 28°C. A petri dish of water and an abundance of ¼- to ½-in. crickets were continuously available in the tanks.

When the lizards were first placed in the tanks, fighting was virtually continuous. Aggressive displays such as head bobs, extensions of dewlap, and push-up displays (Noble & Bradley, 1933) were frequently initiated by any of several lizards. Often as many as four animals would be involved in a single fight. Within 2 days, the level of fighting was greatly reduced, and the majority of aggressive actions were initiated by one lizard. Those initiated by other animals were rarely directed at this "dominant" lizard. The dominant individual moved freely throughout the tank, chasing any other animals in his path. In contrast, the nondominant lizards avoided the dominant and either flattened themselves against the ground or fled at his approach.

On June 1, the dominant lizard was removed from each tank and placed in the observation area (OA). Upon their removal, fighting again erupted in the home tanks, eventuating in the establishment of two new dominant animals. These two served, in turn, for the following week's observations. A new pair of Ss was selected in this manner for each set of observations. The Ss were placed in the OA on a Saturday morning and were observed from the following Monday through Friday for 10 min of each hour, 9:30 a.m.-5:40 p.m. A single mealworm (*Tenebrio larve*) was placed at the center of the area at 11:30, 2:30, and 5:30. Water was continuously available. In all, six pairs were observed, but data on the first pair is incomplete for the first 2 days of observation.

The observation area consisted of a 32-in.-square area, enclosed by a 16-in.-high unpainted plywood wall, and covered with a removable wire mesh top. The floor and walls were marked off into 8-in. squares with ¼-in. black tape. Light and heat were provided from 5:00 a.m. to 9:00 p.m. by a 250-W incandescent bulb, hung 22 in. above the center of the area. The temperature directly under the lamp was thereby maintained at 26°-28°C during the day, dropping to room temperature (approximately 24°C) at night. Two plywood platforms, 1 x 1 x 1½ in., were placed at the center of opposite walls.

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