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INHIBITORY STIMULUS CONTROL IN CONCURRENT SCHEDULES[1]

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Six pigeons were exposed to two keys, a main key and a changeover key. Pecking the main key was reinforced on a variable-interval 5-min schedule when the key was blue and never reinforced when the key displayed a vertical line on a blue background. Each peck on the changeover key changed the stimulus displayed on the main key. Each subject was given two generalization tests, consisting of presentations on the main key of six orientations of the line on the blue background, with no reinforcements being given. In one test changeover-key pecks changed the stimulus; in the other test the changeover key was covered and the experimenter controlled stimulus changes. Both responses to the six stimuli and time spent in the presence of the stimuli gave U-shaped gradients when the changeover key was operative. With most subjects, absolute rates of responding to each stimulus produced unsystematic gradients, whether or not the changeover key was operative.

An organism may be trained to respond in the presence of one stimulus (S+) and not another (S−) by reinforcing responding to S+ only. Several experiments have used generalization tests to investigate the control by S− following inter-dimensional discrimination training in which S+ and S− lie in orthogonal physical dimensions. In these tests, S− and various other stimuli in the same dimension as S− are presented during extinction. It is usually assumed that all these stimuli are equidistant from S+ so that S+ does not differentially affect responding to these stimuli. A common result has been that responding increases as the stimuli get further from S−, producing U-shaped gradients about S− (Honig, Boneau, Burstein, and Pennypacker, 1963; Terrace, 1966; Weisman and Palmer, 1969). Jenkins (1965) regarded these gradients as showing inhibitory control by S−.

To date, demonstrations of inhibitory control by S− are confined to generalization tests following inter-dimensional discrimination training on multiple schedules, where S+ and S− are alternately presented at a single locus with stimulus changes being arranged by the experimenter. The present experiment investigated control by S− following inter-dimensional discrimination training on concurrent schedules. A procedure originated by Findley (1958) was used in which S+ and S− were alternately presented at a single locus, but stimulus changes were produced by the behavior of the subject. Using this procedure with pigeons, two keys are presented, with S+ and S− appearing on one key, and a peck on the second key changing the stimulus.

The standard generalization test (*e.g.*, Guttman and Kalish, 1956) presents all stimuli being used in the test for some fixed period of time in a number of mixed sequences, stimulus changes being arranged by the experimenter. Such a test allows the subject to vary absolute rate of responding to each stimulus but not the amount of time spent in the presence of each stimulus. Absolute rate of responding may be calculated by dividing responses to the stimulus by the time spent in the presence of the stimulus. This test procedure seems appropriate following discrimination training on a multiple variable-interval schedule where a subject is free to vary its absolute rate of responding, but not the time spent in each component. However, with discrimination training on concurrent variable-interval schedules, the subject is free to vary time spent as well as absolute rate of responding in each component; therefore, the standard generalization test may not be the most appropriate.

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Catania (1966) reported that on concurrent schedules pigeons match the proportion of time spent to the proportion of reinforcements occurring in each component. There is evidence that this orderly distribution of time spent is not merely an indirect consequence of the relation between reinforcement and responses, but that pigeons react directly to changes in the distribution of reinforcements between components by varying the proportion of total session time spent in each component (Brownstein and Pliskoff, 1968). Catania (1966) reported that absolute rate in each component tends to remain constant and does not reflect changes in the distribution of reinforcements between components. In view of this, a generalization test that allows for variations in the time spent in the presence of each stimulus might be expected to provide more orderly data. Such a test can be conveniently arranged following discrimination training with the Findley (1958) procedure by permitting pecks on the key on which stimulus changes are scheduled during training to produce stimulus changes during the generalization test. The present experiment investigated the control by S− after inter-dimensional discrimination training on concurrent variable-interval schedules using two generalization test procedures. In one procedure, stimulus changes were arranged by the experimenter; in the other procedure stimulus changes were produced by the subject.

METHOD

Subjects

Six experimentally naive homing pigeons were maintained at 80% (±15 g) of their free-feeding weights throughout the experiment.

Apparatus

A standard two-key pigeon chamber was used (Grason-Stadler model E1184J). The response mechanisms were two translucent keys 4 in. (10.2 cm) apart and 8 in. (20.4 cm) from the floor. Stimuli were projected to the left key by a rear-mounted multiple stimulus projector. The right key was illuminated by a 15-w bulb. A force of 15 g (0.147 N) was sufficient to operate either key. General illumination was provided by a 10-w houselight to the right of the right key. Reinforcement was a 3-sec presentation of grain in a magazine halfway between and 6 in. (15.3 cm) below the two keys. The chamber was enclosed in a refrigerator cabinet. A blower provided ventilation and masking noise. Stimulus events and response dependencies were automatically scheduled. Responses were recorded on counters and a cumulative recorder.

Procedure

Sessions were conducted six days a week, and were usually of 45-min duration.

1. Preliminary training. The birds were trained to feed from the magazine and then to produce the magazine by emitting behaviors successively approximating a peck on the left key. Each of the first 120 pecks on the left key was reinforced. The left key was white, the right key dark and ineffective. In the third and fourth sessions, reinforcement was scheduled for every tenth response, and every thirtieth response, respectively. In the fifth session, reinforcements were arranged according to a variable-interval 1-min schedule (VI 1-min). In this schedule, reinforcement occurred for the first response following varying intervals averaging 1 min since the previous reinforcement.

2. Concurrent pre-training. Beginning in the sixth session, the birds were trained on concurrent VI schedules with identical schedules of reinforcement in each component. The stimuli correlated with the two components were a black cross or circle on a white surround. Both stimuli were projected on the left (main) key. A peck on the right key (changeover or CO key) switched components. During all concurrent training and testing the CO key was illuminated. A changeover delay (COD) specified a minimum delay between a peck on the CO key and the availability of reinforcement for a peck on the main key. A COD of 1.5 sec was used for all concurrent training. Six sessions with VI 2-min in each component (*conc* VI 2-min VI 2-min) were followed by four sessions with VI 5-min in each component (*conc* VI 5-min VI 5-min). Variable-interval schedules were based on a distribution of intervals that produces fairly uniform responding (Fleshler and Hoffman, 1962). The purpose of the concurrent pre-training was to familiarize the birds with the concurrent procedure, particularly the role of the CO key.

3. *Concurrent differential training.* After pre-training, two new stimuli were introduced on the main key. A blue key (S+) was correlated with a VI 5-min schedule, and a black vertical line of 0.125-in. (0.318 cm) diameter on a blue key (S−) was correlated with extinction. The new schedule (*conc* VI 5-min EXT) was in force for each bird until responses in the presence of S− were between 5 and 10% of responses in the presence of S+.

4. *Generalization testing.* In the two sessions after criterion was reached, each bird received two generalization tests. During each test six orientations of the black line on blue background were presented on the main key according to five random series. The lines were ±90°, −60°, −30°, 0° (S−), +30°, and +60° from vertical. No responses were reinforced during the tests. Each test lasted 30 min and was preceded by a 10-min warm-up on *conc* VI 5-min EXT. A 1-min timeout intervened between warm-up and test, allowing time to cover the CO key. During the timeout, the houselight was out and the keys dark. One generalization test was a concurrent test in which the CO key was available and operative, each peck on the CO key effecting a stimulus change. The other test was a multiple test in which the CO key was covered, a stimulus change occurring automatically every 1 min. The concurrent test was given first to S2, S3, and S6 and the multiple test was given first to S1, S4, and S5.

RESULTS

In the last session of concurrent pre-training all birds gave more than 150 pecks on the CO key. Pecks on the CO key increased during differential training for all birds except S1, which gave only 39 CO-key pecks in the session in which it reached criterion.

Differential training resulted in a progressive reduction in three behavior measures in S−: responding to S−, time spent in S−, and absolute rate of responding to S−. For two birds (S1, S5) absolute rate of responding to S+ increased slightly during differential training, but the remaining birds showed a small decrease in rate. A summary of the performance of each bird in its final session of differential training is shown in Table 1. One bird (S6) spent about three times as long in S+ as in S−, four birds (S1, S3, S4, S5) spent between four and six times as long, and one bird (S2) spent about nine times as long. The absolute rate of responding to S+ was generally only two to four times greater than to S−, but for S6 it was six times greater.

Table 1

This table shows time spent, number of responses, and absolute rate of responding, in relation to S+ and S− during the last session of differential training for each bird. Numbers of sessions on differential training (sessions to criterion) are also shown.

Bird	*Sessions to Criterion*	*Stimulus*	*Time Spent (sec)*	*Responses*	*Response Rate (resp./sec)*
S1	7	S+	2435	1949	0.80
		S−	470	186	0.40
S2	6	S+	2099	2521	1.29
		S−	230	99	0.43
S3	5	S+	2480	1442	0.58
		S−	471	71	0.15
S4	6	S+	1985	1535	0.77
		S−	420	151	0.36
S5	6	S+	2052	1248	0.61
		S−	438	103	0.24
S6	4	S+	2364	1161	0.49
		S−	840	64	0.08

The concurrent generalization gradients shown in Fig. 1 are based on the first 15 min of the 30-min generalization test. Towards the end of the test, some birds emitted few CO-key pecks and would allow a stimulus (usually S−) to stay on for a long period, although they did not peck at it. Since this would give a spurious result for time spent in that stimulus it was decided to consider only the first half of the test, where responding on both keys was relatively frequent. One bird (S1) gave no CO-key pecks in the warm-up, and gave only one during the test, almost at the end. Accordingly, no gradient was obtained from this bird, so gradients are shown for five birds only.

The gradients based on time spent in each stimulus are marred slightly by two reversals between 30° and 60°, but are clearly U-shaped gradients. Least time was generally spent in S−, with most time spent in the stimulus most different from it (90°). The gradients based on total main-key responses to each stimulus are similar. The third set of gradients in Fig. 1 is based on absolute rates of responding on the main key, obtained by dividing responses to each stimulus by time spent in that stimulus. Although the mean data revealed a shal-

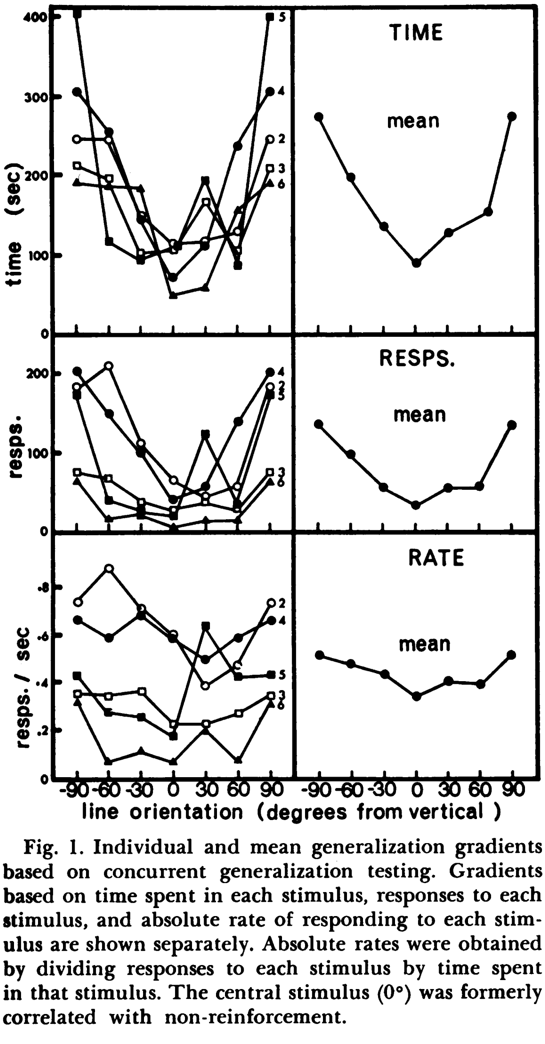

Fig. 1. Individual and mean generalization gradients based on concurrent generalization testing. Gradients based on time spent in each stimulus, responses to each stimulus, and absolute rate of responding to each stimulus are shown separately. Absolute rates were obtained by dividing responses to each stimulus by time spent in that stimulus. The central stimulus (0°) was formerly correlated with non-reinforcement.

low U-shaped gradient, this effect is not shown by all birds.

Gradients for the multiple test are shown in Fig. 2 and are based on the full 30-min test period, with the first cycle of stimuli subtracted. Responses in the first cycle were excluded because some birds did not respond during the first few stimuli. For three birds (S2, S5, S6), the gradients are essentially U-shaped, but for the remaining birds the gradients reveal many reversals of slope, and show no general tendency for rate to increase to test stimuli further from S—. The mean gradient is essentially flat.

DISCUSSION

U-shaped generalization gradients around S— occurred reliably only in the concurrent generalization tests where the birds changed the stimuli by responses on the CO key. With this test procedure, U-shaped gradients typically occurred for two dependent variables, time spent in each stimulus and responses to each stimulus; the absolute rates of responding to stimuli did not show the same effect. With the multiple test procedure the gradients (based on response rate) were not uniformly U-shaped.

The rationale for using the CO key in the generalization tests was to allow the birds the opportunity to vary the time spent in the presence of each test stimulus. If time spent is more sensitive than absolute response rate as a measure of concurrent variable-interval schedule performances then it may be expected to provide more orderly generalization gradients when used as the dependent variable. The present results are consistent with this view and support Brownstein and Pliskoff's (1968) observation that in concurrent schedules time spent in components is a sensitive dependent variable. It is not clear why some birds showed U-shaped generalization gradients of absolute response rate and some did not.

The U-shaped gradients of time spent in the test stimuli may be interpreted as inhibitory gradients only if they are taken to be analogous to response gradients of similar shape. This interpretation is supported by the similarity in this experiment of gradients based on time

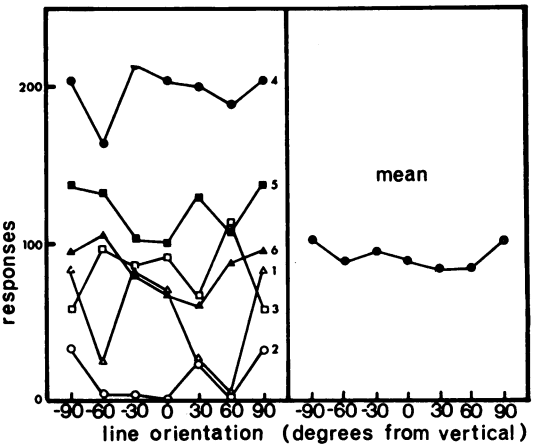

Fig. 2. Individual and mean generalization gradients based on multiple generalization testing. Values on the ordinate are responses to each stimulus. The central stimulus (0°) was formerly correlated with non-reinforcement.

spent in, and responses to, each stimulus. However, it must be recognized that the time spent in a stimulus is also the latency of the CO-key response that terminates the stimulus, and that the gradients of time spent may be regarded as excitatory gradients around S— based on the cumulative latencies of CO-key responses in the presence of each test stimulus. Accordingly, the cumulative latencies of CO-key responses terminating the test stimuli may be regarded as a gradient of excitatory control over an escape response. Interpreting the U-shaped gradients of time spent in the test stimuli as evidence of inhibitory control by S— receives further support from those birds that showed inhibitory gradients of response rate with the multiple test procedure.

Comparison of the present inhibitory gradients following concurrent schedule inter-dimensional discrimination training with those obtained in previous studies following multiple schedule inter-dimensional discrimination training is difficult because of the different dependent variables found to be relevant to the two types of schedule. The present study demonstrates that experimental manipulations that frequently produce inhibitory control by S— in multiple schedules can also produce inhibitory control by S— in concurrent schedules. It remains to be shown whether other phenomena that follow experimental manipulations in multiple schedules can be demonstrated following similar experimental manipulations in concurrent schedules.

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