RESPONSE RATE, LATENCY, AND RESISTANCE TO CHANGE

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Pigeons were trained on a multiple variable-interval/variable-interval schedule with pacing contingencies that generated high response rates in one component and low response rates in the other. Timeout periods separated the schedule components. During resistance-to-change tests, response-independent food was presented during the timeout periods, and the duration of that food presentation was varied among test sessions. Response rates in the schedule components decreased and latencies to the first response increased as a function of the duration of food presentations during the timeout. Both dependent measures changed about the same amount relative to their own baseline levels. The conclusions are that baseline response rates controlled by pacing contingencies are equally resistant to change, given equal reinforcement densities, and latency is a sensitive measure of resistance to change.

Key words: response strength, resistance to change, multiple schedules, pacing schedules, pigeons

Response strength can be defined in terms of relative resistance to change (Bouzas, 1978; Mandell, 1980; Nevin, 1974, 1979). Two or more response rates may be established in the presence of different discriminative stimuli (S^D s). When responding has stabilized, some operation, such as the introduction of response-independent food in the presence of another S^D , can be added. If responding in the presence of the original S^D s is disrupted, changes in response rates, relative to their own baselines, are taken as indices of response strength. Responding that shows the greater change from baseline is said to be weaker, whereas that which is less changed is identified as stronger.

Nevin (1974, Experiment I), for example, used a three-ply multiple schedule (variable interval 1-min/extinction/variable interval 3-min) in which responses were reinforced with food on one schedule in the presence of a red keylight and on a different schedule when the

key was green. A third, dark-key, condition intervened between presentations of the schedule components. Once responding had stabilized, response-independent food was introduced during dark-key periods. Response rates in both VI schedule components decreased as a direct function of the frequency of response-independent food; however, responding associated with the higher baseline reinforcement rate was less disrupted than that associated with the lower rate of reinforcement. Nevin also found responding to be less disrupted when a shorter delay of reinforcement, or when a larger reinforcer, was used in one component of a multiple schedule. Such findings suggest the functional equivalence of density, delay, and magnitude of reinforcement in the determination of relative resistance to change. They also demonstrate the unifying effect of measuring response strength using resistance to change.

Although resistance to change is influenced by reinforcement variables, these variables also influence response rates directly. Therefore, the effects of reinforcement may be confounded with response rate effects. Indeed, Nevin (1974, 1979) noted that the evaluation of response strength solely in terms of response rate differences (e.g., Herrnstein, 1961, 1970, 1974) is complicated because rate is a conditionable dimension of behavior (cf. Anger, 1956, 1973;

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Blough, 1963; Blough & Blough, 1968; Malott & Cumming, 1965; Mandell, 1980; Morse, 1966; Shimp, 1968, 1974; Staddon, 1968; Wilkie & Pear, 1972; Williams, 1968). Thus, Nevin tested the possibility that measurement of strength in terms of resistance to change may be meaningful only when comparing performances maintained by similar contingencies. In Experiment V of his 1974 study, a three-ply multiple schedule was used, and differential contingencies on response rate (fixed-ratio 3, limited hold 3-sec [DRH], or interresponse time greater than or equal to 3 sec [DRL]) were placed in tandem with either VI 1-min or VI 3-min schedules, such that high and low response rates were maintained by different frequencies of reinforcement. Resistance to change was assessed by introducing response-independent food during dark-key periods. The data for two of the four subjects indicated that performances maintained under DRL were more resistant to change than those maintained by the DRH contingency when reinforcement densities were equal.

The differences in disruptability observed by Nevin may be attributed to differences in the programming of the rate contingencies used in each component. Reinforcement for DRL responding, once set up, was available until the end of the schedule component, whereas that for DRH responding was canceled after 3 sec. Such programming of rate contingencies created a bias in favor of responding maintained by the DRL contingency since subjects stood a better chance of obtaining reinforcement even after very long pauses under that condition. In contrast, reinforcement under the DRH condition was unlikely unless the subject was responding as the VI timer reached the end of its cycle. Long pauses, as are seen when response-independent food is introduced, result in differences in reinforcement density between the two schedules. When reinforcement is more likely in one condition than in another, greater resistance to change in the associated behavior is to be expected (Fath, 1979).

In the present study, rate of reinforcement was held constant, and the rate at which responding occurred was altered by placing contingencies on response rate in a manner that would not influence reinforcement density. In addition to measuring relative resistance to change using response rates, latency to respond

was evaluated as a possible index of the disruptive effects of response-independent food.

METHOD

Subjects

Six naive, barren-hen White Carneaux pigeons, approximately seven years old, were maintained at 80%, $\pm$ 5%, of their free-feeding weights. Grit and water were freely available in the home cages throughout the experiment.

Apparatus

Three two-key Lehigh Valley Electronics pigeon testing chambers were used. The right key in each chamber remained unilluminated and inoperative throughout the experiment. The left key, which required a minimum force of .2 N to operate, was illuminated from behind by an Industrial Electronics Engineers one-plane readout projector. Kodak wratten filters were used to provide red and green stimuli. The three chambers were interfaced (State Systems, Inc.) with a PDP8-F mini-computer (Digital Equipment Corp.) located in an adjacent room. Scheduling of stimulus events, reinforcement contingencies, and data collection were accomplished using Time-Share SUPERSKED software (State Systems, Inc.).

Procedure

Subjects were trained to eat from the food hopper and were then exposed to three sessions of an autoshaping procedure. Next, the procedure was changed to a response-contingent arrangement (multiple VI 1-min/EXT/VI 1-min). The duration of each VI schedule component was 60 sec. An extinction schedule was correlated with a dark response key, presentations of which lasted 30 sec. The selection of the initial VI-schedule component for each session was random following the first dark-key period. Thereafter, VI-schedule components alternated regularly with dark-key periods intervening. The interval values for the VI schedules were selected randomly within each session from independent arithmetic series associated with each stimulus condition. Food presentations lasted five sec. Sessions terminated after the 40th VI-schedule component.

Contingencies on response rate were introduced in Session 51 and were of the form described by Ferster and Skinner (1957) as VI

Fig. 1. Mean response rate (dashed lines) and mean latency as a function of response-independent food magnitude. Triangles indicate the low-rate component and circles the high-rate component. Brackets around baseline points represent one standard deviation around the mean.

spacing (2), T1 sec to T2 sec. Under this arrangement, once a VI timer reaches the end of its cycle, only responses that terminate IRTs that fall within specified bands are reinforced. In our study, bandwidths were held constant at 1 sec. The DRL band was 2.5 sec to 3.5 sec, and the DRH band was .5 sec to 3.5 sec. In addition to the modified response-rate contingencies, our procedure also differed from Nevin's (1974, Experiment V) in that reinforcement, once available, remained so until collected. If a schedule component terminated before a reinforcer was collected, the reinforcer was available at the beginning of the next component, at which time the pacing requirement was reset.

After 50 sessions with the multiple-pacing contingencies in effect, testing began. On test days, response-independent food was made available during dark-key periods. The onset of response-independent food presentations al-

ways occurred 10 sec after the onset of each dark-key period. The duration of hopper presentations was varied. Six levels of the independent variable (magnitude of response-independent food presentation) were used. Free food presentations ranged from 2.5-sec to 15.0-sec duration in 2.5-sec increments. Order of presentation was randomized for each subject, and each animal was exposed to each level of the independent variable three times. Each test lasted one session, and a baseline recovery period of six days was allowed between test sessions.

RESULTS

The data collected for each session included the number of responses, scheduled and collected reinforcers, and trial-by-trial latencies to respond in the presence of each color stimulus. If no response occurred in the presence of

Fig. 2. Latency as a function of trials within sessions of response-independent food presentation (Subjects 1 and 2).

a given stimulus, a value of 60 sec, the component duration, was recorded in the latency counter associated with that trial.

Figure 1 shows response rates and latencies to respond for individual subjects plotted on three-cycle semilogarithmic coordinates. When data are presented in this way, the slopes of the functions indicate the degree of resistance to change. With regard to response rate, a greater negative slope across values of the independent variable indicates less resistance to change, and responding is identified as weaker. When latency is taken as a measure of resistance to change, weakness is reflected in a positive slope. (See Nevin, 1979, and Schmid and Schmid, 1979, for further discussion of the semilogarithmic plot.)

The data in Figure 1 demonstrate functional relationships between both dependent measures and the magnitude of response-independent food presentations during dark-key peri-

ods. As the amount of response-independent food increases, mean response rates decrease and mean latencies increase. Between-subject comparisons of the slopes for the mean response rate functions show that high and low response rates were equally affected by the introduction of another source of food. Similarly, except for more variability, mean latencies vary linearly with increases in the magnitude of response-independent food presentations. Generally, comparison of the response rate and latency functions reveals consistency between the two measures.

The data in Figures 2, 3, and 4 show the effects of response-independent food on latency-to-respond for individual subjects, within randomly selected sessions, for the baseline period and three levels of the independent variable. Latencies are shown for each subject as a function of trials within single sessions. For presentation purposes, a trial is arbitrarily

Fig. 3. Latency as a function of trials within sessions of response-independent food presentation (Subjects 3 and 4).

defined as the successive occurrence of one red and one green stimulus. Dashed lines across the tops of the graphs represent the durations of schedule components.

Beginning with the leftmost panels (base-lines), S-1 and S-2 (Figure 2) show differentiation between the two functions. For these two subjects, latency was affected by the contingencies on response rate. The ordering of the functions is consistent with the ordering of the rate contingencies. Longer latencies are associated with lower response rates, whereas shorter latencies are associated with high response rates. The baseline data for the remaining subjects (Figures 3 and 4) show no such effect. The remaining data in Figures 2, 3, and 4 illustrate the effects of three levels of response-independent food magnitude. As the magnitude of response-independent food presentations increases, there is a general increase in latencies both within and across sessions,

except at the extreme low value of the independent variable, where latency is little affected. Only one panel shows departure from this trend. The data for S-6 (Figure 4) show a consistent decline in latency across the session in which response-independent food magnitude was 7.5 sec.

DISCUSSION

Our results demonstrate that different response rates maintained by schedules producing equal reinforcement densities are equally resistant to change. As the magnitude of response-independent food presentations increased, response rates decreased and latencies increased. Both response rate and latency functions showed equivalent changes with the introduction of response-independent food. Although our results differ from those reported

Fig. 4. Latency as a function of trials within sessions of response-independent food presentation (Subjects 5 and 6).

by Nevin (1974, Experiment V), those differences can be explained in terms of the manner in which the rate contingencies were programmed. Specifically, when pacing contingencies were programmed in an unbiased manner that did not interact with reinforcement density, the effects of the disruptive operation were equal. Our results support Nevin's approach to the quantification of response strength and also emphasize the sensitivity of resistance to change to small changes in contingency manipulations.

Blackman (1968) suggested that high response rates may be less resistant to change because subjects responding at high rates necessarily make more responses per reinforcement than those responding at low rates. Thus, behavior with which the ratio of responses to reinforcements is high may be more susceptible to suppressive operations. Our data demonstrate that rate contingencies did not affect response strength. Thus, questions arise regarding the validity of Blackman's hypothesis. However, since we used pigeons and Blackman used rats as subjects, perhaps the difference in results may be attributed to species-specific differences in the ability to sustain high response rates.

The use of resistance to change to assess response strength implies that various dependent measures of responding change in a consistent manner with the parameters of reinforcement when a disruptive operation is introduced. To date, however, only rate changes have been used as a dependent measure. Our data demonstrate that latency changes also index resistance to change. These results, then, strengthen the conceptual linkage between resistance to change and response strength by permitting its computation using a second measure of behavior. It could be argued that latency is a sample of response rate and, as such, would be expected to covary with rate. This, however, does not appear to be the case since the data for only two of the six subjects showed differences between latencies associated with the high- and low-rate components during the baseline condition. If latency were simply a sample of rate, such differences should have been evident for all subjects. This separation of rate and latency justifies the use of latency as a second index of resistance to change and extends the generality of Nevin's

conceptualization of response strength as resistance to change.

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