A COMPARISON OF DIFFERENT MEASURES OF RESPONSE STRENGTH IN THE STUDY OF STIMULUS GENERALIZATION¹

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In Experiment 1, three pigeons were given variable interval training to peck at a light of 550 $m\mu$ and then were tested for stimulus generalization in extinction to several different wavelengths. A gradient was obtained for latency of the first response in each test period, for the number of test periods in which responding occurred, and for the measure of response rate. When the response rate gradient was corrected for differences in initial latency and in number of responded trials, the change was minimal, indicating that the major component of response rate as usually measured is rate of responding having once responded. In Experiment 2, three other pigeons were trained to respond to 550 $m\mu$ (for variable interval reinforcement) and not to 570 $m\mu$ (extinguished). Analysis of generalization gradients dictated the same conclusion as that reported for generalization following single stimulus training.

The basic technique for studying the stimulus generalization of an operant response developed by Guttman and Kalish (1956) has become an accepted standard in the field. The essential characteristics are the use of a training schedule which generates a stable baseline with great resistance to extinction (*e.g.*, variable interval) and the use of a generalization test in extinction which consists of many short periods of exposure to a wide range of stimuli, including the original conditioned stimulus (S^D). During this test, each of the test stimuli is presented equally often and the total number of responses to each stimulus, summed or averaged over all of its presentations, constitutes the gradient. A variant of this procedure maintains response strength by continuing to reinforce responses to the S^D during the generalization test.

As Blough (1963, 1965) has pointed out, "response rate" thus measured is statistically and conceptually treated as unitary, which it clearly is not. First of all, test periods with zero responding are averaged in with periods of responding to determine the response "rate" for each stimulus. If response rate during periods of responding were invariable, differences

in number of periods in which responding occurred might account for a "rate" gradient artifactually. Consider the even more obvious confounding of rate with latency. Hiss and Thomas (1963) have reported that the latency of the first response in each test period is shortest to the S^D and increases systematically with distance from this value. If systematic latency differences do exist, and if response rate following the first response in each period were invariable, differences in initial latency might also produce an artifactual "rate" gradient.

The confounding of response rate with other measures of response strength in a Guttman-Kalish generalization test is indisputable. Though it seems unlikely that differences would exist in number of zero response trials and in initial latency while response rate following the first response in a test period remained invariable, the relative contributions of these three different response strength measures to the gradient of "response rate" as usually measured remain to be determined. For this purpose the present investigation was performed.

EXPERIMENT 1

Subjects

Three homing pigeons, obtained locally, were maintained at approximately 75% of free-feeding weight throughout the study.

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Apparatus

Two automatic key-pecking apparatuses, described in detail by Hiss and Thomas (1963), were employed. Stimuli of 510, 530, 550, 570, and 590 $m\mu$ were provided by Bausch and Lomb interference filters, not corrected for brightness differences.

Procedure

Following magazine and key peck training, subjects, designated #4, #9, and #10, each received two days of 40 continuous reinforcements and then were placed on a variable interval reinforcement schedule with a mean inter-reinforcement interval of 60 sec for five daily half-hour sessions. A light of 550 $m\mu$ continuously illuminated the key and all reinforcements were of 3-sec duration. Next, subjects were given eight additional half-hour sessions of the same schedule but with 10-sec periods of blackout (time out) between 50-sec periods of stimulus exposure; 550 $m\mu$ was present during stimulus exposures and no reinforcements were available during blackouts.

On the day after the 10th variable interval session, a 5-min warm-up period of variable interval reinforcement was followed by a generalization test in extinction. Five stimuli (510, 530, 550, 570, and 590 $m\mu$) in 12 different random series were each presented for 50 sec followed by a 10-sec blackout during which the stimulus was changed and the number of responses in the preceding period recorded. Latency of the initial response in each stimulus period was also measured throughout the test.

RESULTS AND DISCUSSION

The major portion of Fig. 1 is devoted to the generalization gradients of the three subjects and the mean gradients for the group based on three different response "rate" measures. The first measure is the conventional (uncorrected) one based on all trials. The contribution of zero response trials is subtracted from the uncorrected gradient by basing the mean values on only those trials when some responding occurred. The appropriateness of this correction is demonstrated by the inserts which indicate that a gradient of number of responded trials does indeed exist.

The final correction of the response rate measure occurs by computing the means on

Fig. 1. Conventional (uncorrected) generalization gradients compared with generalization gradients corrected for initial latency and zero response trials in Exp 1. CS, conditioned stimulus.

the basis of only the responded portion of each trial (*i.e.*, that portion subsequent to the first response). As the inserts indicate, a gradient of initial latency (*i.e.*, latency of the first response in each stimulus presentation period in which responding occurs) does exist in this situation. Such a gradient has been reported by Hiss and Thomas (1963) but was not found in a punishment study with rats recently reported by Winograd, Cohen, and Cole (1965).

The fact that both response latency and number of responded trials constitute a gradient suggests that the corrections should alter the rate scores to the peripheral stimuli proportionately more than to central ones. Since rate of responding, having once responded, is much higher to the conditioned stimulus than to the other values, however, a proportionately small change may result in an absolutely large one. Thus, the extent of the confounding of the response rate gradient depends on the magnitude of the differences in latency and in number of responded trials. Where these are relatively small their influence on the rate gradient is quite limited.

It is clear from Exp 1 that differences in number of responded trials and in initial latency both contribute little to the gradient of response rate as usually reported. When corrected for such confounding, the rate gradient is slightly elevated but remains unchanged in slope or form. The fact that the confounding of response rate with the other measures is of little consequence in the simple case of generalization testing following single stimulus training does not preclude the possibility of a more significant role when additional variables are manipulated. To test this possibility, the effects of successive discrimination training on stimulus generalization were studied in Exp 2, with and without correcting the rate gradient for confounding.

EXPERIMENT 2

Subjects

Three locally obtained homing pigeons were maintained at approximately 75% of free feeding weight.

Procedure

Using the same apparatus, the subjects, designated #16, #17, and #18, were trained as in Exp 1 except that on the day after the black-

out was introduced, discrimination training was begun. A stimulus of 570 $m\mu$ (S-) was randomly alternated with 550 $m\mu$ (S+), each exposure being 50 sec in duration and each followed by a 10-sec blackout; no reinforcements were available during the 570 $m\mu$ exposures or the blackout periods. A criterion of zero responding on five successive S- trials, combined with continued responding to S+, was met in 4, 5, and 6 days by subjects #16, 17, and 18 respectively. Each subject was tested in the same manner as in Exp 1 on the day after criterion performance.

RESULTS AND DISCUSSION

The data in Exp 2 were analyzed in the same manner as in Exp 1. Mean response rate for each stimulus was computed for each subject on the basis of all test trials, only on trials on which responding occurred, and only on the responded portion of each trial. The resulting generalization gradients are presented in Fig. 2 for each subject and for the group. In the inserts are the gradients of mean latency and number of trials on which some responding occurred.

Successive discrimination training tends to produce a shift in the peak of responding from S+ in a direction away from S- (Hanson, 1959, Thomas, 1962). No actual peak shift was observed here since the test stimulus values were so widely separated, but the asymmetry of the obtained gradients suggests that a peak of responding would have occurred at a value between 530 and 550 $m\mu$, had one been included in the test. The only data point markedly influenced by the correction procedure is that for 510 $m\mu$ which is based on a small number of responded trials and is thus of questionable reliability. Aside from this point, it is clear that the confounding of the response rate gradient following discrimination training is little greater than it was following single stimulus training. It may thus be noted that introducing discrimination training does not affect the measures of initial latency and number of responded trials in a manner which consistently increases their limited influence on the gradient of response rate.

On the basis of both Exp 1 and 2 it is safe to conclude that gradients of response rate obtained in a Guttman-Kalish type of generalization test are based primarily on the measure

Fig. 2. Conventional (uncorrected) generalization gradients compared with generalization gradients corrected for initial latency and zero response trials in Exp 2. Where no value appears for the 590 mμ stimulus for subjects #16 and #18 with the measures of latency and corrected rate, no responses were made to this stimulus. The group mean for these measures at 590 mμ is thus based solely on the contribution of subject #17.

of rate of responding having once responded. This measure may be said to vary systematically as a function of the stimulus employed in generalization testing, being greatest to the conditioned stimulus and decreasing gradually and monotonically as stimuli increasingly removed from the conditioned stimulus are introduced. Although gradients may also be obtained in the Guttman-Kalish situation with the measures of initial latency and number of responded trials, response rate is both more sensitive and more reliable than either of these alternatives and is thus more appropriate to serve as the dependent variable in formulating basic principles of generalizing behavior.

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